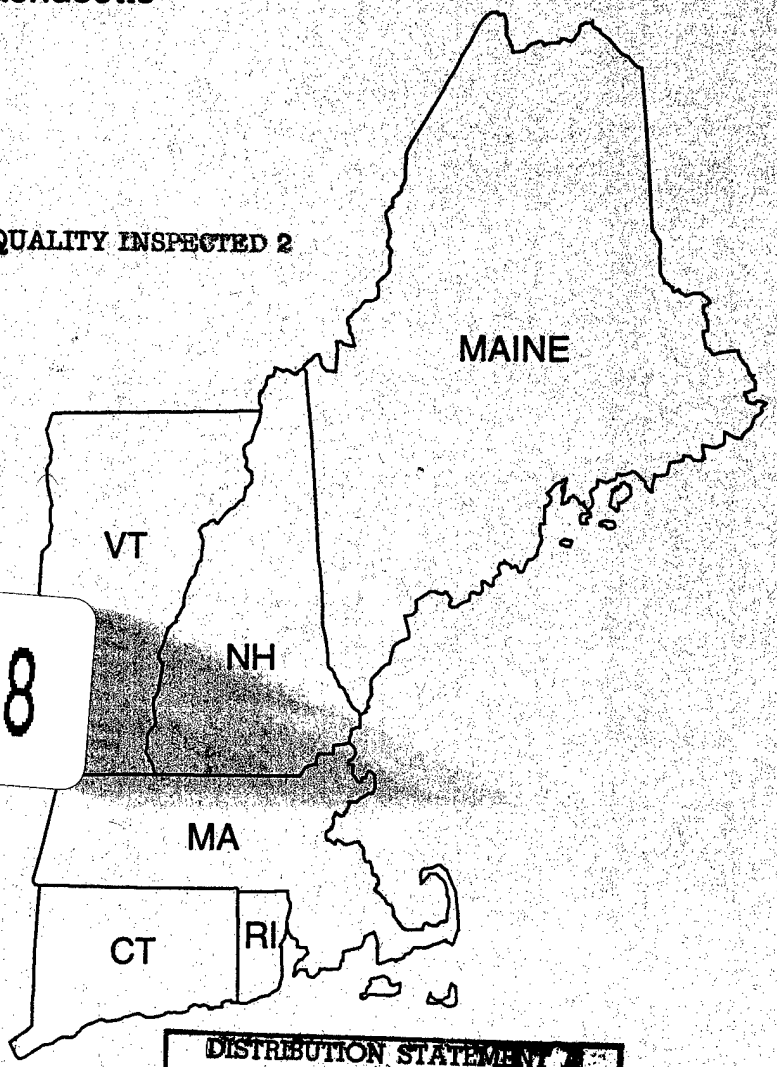
US Army Corps
of Engineers
New England Division

The National Study of Water Management During Drought

THE NEW ENGLAND DROUGHT STUDY: Water Resources Planning for Metropolitan Boston, Massachusetts



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The study has traced the water resources planning experience for the metropolitan Boston area from the 17th century to the present in order to investigate how current planning has evolved from seeking large capital intensive structural solutions to potential water supply (source) shortfalls to more recently favoring less costly non-structural solutions. The study found that the introduction of citizen participation into the planning process was central to this change. The drought of the 1960s precipitated a debate between the operators of the metropolitan Boston water system and interested citizens and citizens' groups, who were opposed to a structural solution to a perceived supply shortfall. Today the managers of the Massachusetts Water Resources Authority/Metropolitan District Commission Water System employ a managerial approach called Trigger Planning. Trigger Planning involves systematically monitoring supply and demand while both undertaking the necessary actions to avoid a supply shortfall such as demand management and preparing to undertake structural solutions if they become necessary. Trigger Planning is the subject of a separate study.

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The National Study of Water Management During Drought

THE NEW ENGLAND DROUGHT STUDY

Water Resources Planning for Metropolitan Boston, Massachusetts

January 1994

EXECUTIVE SUMMARY

The New England Drought Study is one of several regional study components or case studies of the National Study of Water Management During Drought (The National Drought Study). The principal objectives of the National Drought Study are to review how water is managed in the United States, and to develop a strategy to improve water management during drought. The main study report, Managing Water for Drought, is a guide to the drought preparedness method tested and refined in case studies across the country.

The case studies are required to satisfy two objectives:

- to help to achieve the principal objective of the National Drought Study or to develop a better way of managing drought in the United States,
- to leave the region better prepared for drought.

The New England Drought Study has been conducted in the six New England states (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut) in two phases over a three year period beginning in FY 91. Phase I was devoted to the selection of a case study for Phase II. Selection was based on the degree of vulnerability of the entity to drought, the value of the experience nationally in dealing with drought, and the willingness of the state or agency to participate in the study. The study for Phase I recommended that the Massachusetts Water Resources Authority/Metropolitan District Commission (MWRA/MDC) Water System be the case study for Phase II.

During Phase II, two studies have been conducted. The first entitled, Water Resources Planning for Metropolitan Boston, Massachusetts is the subject of this report. TRIGGER PLANNING: Integrating Strategic, Tactical and Emergency Planning into a Single Water Resources Management Process is the object of a separate report.

The study has traced the water resources planning experience for the metropolitan Boston area from the 17th century to the present in order to investigate how current planning has evolved from seeking large capital intensive structural solutions to potential water supply (source) shortfalls to more recently favoring less costly non-structural solutions. The study found that the introduction of citizen participation into the planning process was central to this change. The drought of the 1960's precipitated a debate between the operators of the metropolitan Boston water system and interested citizens and citizens' groups, who were opposed to a structural

solution to a perceived supply shortfall. Since that time planning has evolved from a classical or episodic approach to a managerial approach to balancing future demand and supply for a water system. Figure 7 presents a schematic characterization of both approaches.

The episodic approach was characterized by periodic assessments of future demands on the water system and of the system's capacity to satisfy these demands followed by system improvements and then succeeded by periods in which the system would be expected to run on its own. Supply was considered to be variable, that is, new sources could be found. Future demand was based on projections of population and water use and these were considered to increase in the future. During this time, structural solutions to potential shortfalls in water supply were favored.

Today, the managers of the Massachusetts Water Resources Authority/Metropolitan District Commission Water System (MWRA/MDC) employ a managerial or interventionist approach to planning called Trigger Planning. Rather than permitting the system to move toward the inevitability of a future condition, whether desirable or undesirable, system managers take action to direct the system to preferred future. A two pronged approach to potential shortfalls in supply is employed: non-structural and structural solutions. The approach involves systematically monitoring supply and demand while both undertaking the necessary actions to avoid a supply shortfall and preparing to undertake structural solutions if they become necessary. Non-structural solutions (demand and supply management, drought management planning, shorter horizon demand forecasting, etc.) are designed to wring more use from the current water supply infrastructure through more efficient water use while reducing potential system use through conservation.

The MWRA/MDC Water System represents an area of the country that has not experienced a serious drought since the 1960's. It is also typical of water supplies for many urbanized communities in the United States with aging municipal and industrial water supply infrastructures, and perhaps lacking redundancy, which are not only in need of capital improvements, but must face the challenges of satisfying future demands. In addition, communities are obliged to respond to federal laws, such as the Safe Drinking Water Act, which may require additional funds to preserve current levels of supply or may effectively reduce available supply. For these reasons lessons learned from the metropolitan Boston water supply planning experience may have wider national application. More details are provided in Chapter 6.

The following lessons learned have been distilled from the metropolitan Boston water resources planning experience.

- Entities responsible for municipal and industrial water supplies should take into account the views of those who could potentially be affected by the decisions made in managing the system. The MWRA/MDC experience demonstrates that these views emanate from geographical areas from which new sources of water could be drawn from current and future water users.

- M&I water system management should encourage an openness to the values of all citizens and citizens' groups with respect to the planned use of water and related land resources. Citizen participation, as an early critic, broadens the planning process and reduces the risk of unanticipated opposition further on in the planning process. An independent citizens' advisory committee supported with funding from the water supply agency, provided with access to the agency and its data, and staffed by competent staff can increase citizen oversight of and participation in water management.

- System managers should be receptive not only to citizen concerns but also to public input into the water system planning process that is consistent with the effective management of the water system. Consensus generated programs should be adopted and funded and committed and competent staff engaged to undertake them.

- Entities responsible for the delivery and distribution of M&I water should be independent and financially autonomous in order to permit them to plan and execute the most cost effective ways of carrying out their missions and to raise the required funds to support their programs.

- The adoption of improved water supply management practices (including demand and drought management, conjunctive use of surface and ground water resources, water exchange agreements, etc.) to fine tune M&I water systems can permit managers to wring additional usage out of their systems without incurring the additional capital costs associated with large projects. In addition, the adoption of these practices improves the credibility of M&I system managers and reduces discord between managers of the system and those citizens and citizens' groups primarily interested in protecting other basin water resources for current and future uses.

- As demand management becomes part of normal operations of the MWRA/MDC Water System, the amount of water use reduction that could be anticipated from drought response actions (see Table 3) may effectively be decreased, thereby trimming the potential reductions that could be expected from implementation of the Drought Management Plan. In this case, well-managed systems will require a reconsideration of drought response strategies.

- The MWRA is developing a decision-making process for water management called Trigger Planning. A current application of Trigger Planning is a feedback process for management which integrates strategic, tactical or drought contingency, and emergency water resources planning into a single management approach. This approach avoids the drawbacks of episodic planning, such as permitting the water system to move towards the inevitability of an undesirable future situation and premature investment. Trigger Planning translates into the postponement of thresholds at which drought emergency measures and long term supply augmentation would have to be considered and/or implemented. This application of Trigger Planning is of particular significance for systems with large over year storage, where reductions in demand during droughts can be carried over into successive years, thereby enhancing the system's long term adequacy.

GLOSSARY OF ABBREVIATIONS

BCB	Boston City Base
CRC	Connecticut River Committee (Connecticut)
CRIC	Connecticut River Information Clearinghouse
CT	Connecticut
DEM	Department of Environmental Management (Massachusetts)
DEP	Department of Environmental Protection (Connecticut and Massachusetts)
DES	Department of Environmental Services (New Hampshire)
DPUC	Department of Public Utility Control (Connecticut)
EIR	Environmental Impact Report
EOEA	Executive Office of Environmental Affairs (Massachusetts)
MA	Massachusetts
MDC	Metropolitan District Commission (Massachusetts)
M&I	municipal and industrial (water supply)
ME	Maine
MEMA	Maine Emergency Management Agency
MEPA	Massachusetts Environmental Policy Act
mgd	million gallons per day
MOU	Memorandum of Understanding
MSCCR	Massachusetts Steering Committee on the Connecticut River
MWRA	Massachusetts Water Resources Authority
National Drought Study	National Study of Water Management During Drought

GLOSSARY OF ABBREVIATIONS (Continued)

NCAC	Northfield Citizens Advisory Committee
NED	New England Division, Corps of Engineers
NEPA	National Environmental Policy Act
NEWS	Northeastern United States Water Supply Study
NH	New Hampshire
OPM	Office of Policy and Management (Connecticut)
RI	Rhode Island
VT	Vermont
WRC	Water Resources Commission (Massachusetts)
WRCC	Water Resources Coordinating Council (Rhode Island)
WSCAC	Water Supply Citizens Advisory Committee

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THE STUDY

The National Drought Study

The New England Drought Study is one of a number of regional study components or case and topical studies in the National Study of Water Management During Drought (The National Drought Study). The National Drought Study is managed by the U.S. Army Corps of Engineers, Water Resources Support Center, Institute for Water Resources, Fort Belvoir, Virginia. The principal objective of the National Study is to review the ways that water is managed in the United States, engage the water management community in a number of case studies over specific approaches to the problem and develop a strategy to improve water management during drought.

The national study is a Corps of Engineers response to the droughts that occurred throughout the United Stares from 1986 to 1988 and which continue in some regions today. The plan was developed by Corps' senior staff and four managers from outside the Corps through a series of questionnaires and workshops. They were designed to elicit the greatest regional concerns with respect to water management during drought and to develop a plan of study to address these concerns.

To initiate the study, the Assistant Secretary of the Army (Civil Works), Robert Page, wrote in early 1990 to the governors of the 50 states and Federal agencies with drought responsibilities eliciting their perspectives on drought issues and requesting their participation in and points of contact for the drought study. The responses from the six New England states mark the point of departure for the New England Drought Study.

The New England Drought Study

Phase I of the three year New England Drought Study was devoted to the selection of a case study in the six state New England region for Phase II based on vulnerability to drought, the value of the drought planning experience to other parts of the country and the willingness of staff to participate in Phase II. The vulnerability to drought and capability to conduct a joint study were assessed for each state in Phase I. Connecticut, Rhode Island, and Massachusetts had considerable concerns about future droughts Massachusetts agreed to collaborate. Rhode Island

and Connecticut were unable to but expressed an interest in the study results. The report for Phase I, completed in July 1991, recommended the selection of the Massachusetts Water Resources Authority/Metropolitan District Commission (MWRA/MDC) as the focus for Phase II of the study.

Phase II has two components. The first is the subject of this report. It is the presentation of the MWRA/MDC water resources planning experience from its initial response to the 1960's drought in seeking to develop new supplies to more recent planning based on demand and supply management, which has obviated the need for new supplies while leaving MWRA's 2.5 million customers less vulnerable to drought. The second component is the development of a feedback process for management called Trigger Planning. It is aimed at the identification and monitoring of leading indicators of potential imbalances of the supply and demand of water in order to schedule the required actions for ensuring that the future supply of water is adequate in quantity, quality and reliability to meet future demand. Trigger Planning is the object of a separate report.

STUDY AUTHORITY

The National Drought Study is being conducted under the authority of and in partial response to Sections 707 and 729 of the Water Resources Development Act of 1986. Section 707 entitled, "Capital Investment Needs for Water Resources", authorizes the Secretary of the Army to prepare and submit to Congress an estimate of the long term capital needs for water resources programs under his jurisdiction, including but not limited to:

- deep draft ports
- inland waterway transportation
- flood control
- municipal and industrial water supply
- hydroelectric power
- recreation
- fish and wildlife conservation

Section 729 regarding the "Study of Water Resources Needs of River Basins and Regions" authorizes the Secretary of the Army for Civil Works, in coordination with the Secretary of the Interior and in consultation with appropriate Federal, State and local agencies, to study the water resources needs of river basins and regions of the United States.

STUDY AREA

The study area for The New England Drought Study is comprised of the six New England

States: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont. The focus for Phase II is the MWRA/MDC Water System.

STUDY OBJECTIVE

The New England region was selected as one of the case studies for the National Drought Study for several reasons. It represents an area of the country that has not experienced serious widespread drought since the 1960's. Also New England has a number of water supply systems that are typical of a large number of urbanized communities in the United States with aging municipal and industrial water supply infrastructures, and perhaps lacking redundancy, which are not only in need of capital improvements, but also must face the challenges of satisfying future demands.

According to the guidelines established by the National Drought Study, the case studies must satisfy two objectives:

> "to help achieve the principal objective of the National Study of Water Management During Drought, which is to develop a better way to manage water during drought in the United States;
>
> to leave the region better prepared for drought."

The two components of the New England Drought Study included in Phase II have been designed to respond to the national study objectives. The MWRA/MDC water resources planning experience component aims to describe, analyze, enhance and present the MWRA/MDC strategic, drought contingency and emergency water resources planning experience and to identify water systems where the experience can be applied. It is the subject of this report. The Trigger Planning component seeks to make a positive contribution to the region by assisting the MWRA/MDC in extending its current planning experience by developing techniques to enhance decision-making for ensuring that future water supplies are adequate in quantity, quality and reliability to meet future demand. Trigger Planning is the object of a separate report.

OTHER NATIONAL DROUGHT STUDY REPORTS

- The U.S. Army Corps of Engineers, Institute for Water Resources (IWR), The National Study of Water Management During Drought - Report of the First Year of Study, May 1991.

- Corps of Engineers, Davis, California, Hydrologic Engineering Center, A Preliminary Assessment of Corps Reservoirs, Their Purposes, and Susceptibility to Drought, September 1991.

- Planning and Management Consultants, Ltd., Carbondale, Illinois, An Assessment of What is Known About Drought.

- Advisory Council on Intergovernmental Relations, Washington, DC, Intergovernmental Coordination for Drought Related Water Resources Management, 1990.

- Resources for the Future, Washington, DC, Integrated Framework for a National Water Management Under Drought Study, Undated.

- U.S. Army Corps of Engineers, New England Division, The Study of the Vulnerability of New England to Drought, Phase I, July 1992.

- Planning and Management Consultants, Ltd., Carbondale, Illinois, Lessons Learned from the California Drought (1987-1992).

A complete list of reports is in Attachment B.

Chapter 2
INTRODUCTION

PURPOSE

The purpose of Part I of this report is to trace the planning experience for the supply of water to the metropolitan Boston area and to identify areas of success and applicability to municipal water supply systems in other parts of the country. Of particular interest is the period since the 1960's when a number of conditions came together to change how water resources were planned to meet projected shortfalls in the demand for water.

BACKGROUND

The 1960's drought in New England set the scene for changes in the way that water resources were planned for municipal and industrial water supply to the metropolitan Boston region. A conflict ensued. The conflict was basically between two different philosophies on how water should be planned, managed and used: structural solutions versus managerial solutions. The source of the conflict developed from concerns of individuals who wished to protect the resources of the Connecticut River Basin.

The structural or capital intensive projects had long been a product of the water supply community. They stemmed from the engineering mission to seek civil works solutions to potential water supply shortfalls, and favored large scale projects that could function with minimal human intervention. This approach to providing metropolitan Boston with potable water had been questioned for some time, but opponents had been unable to muster the arguments and support until such time as citizenry felt so strongly against a proposed solution that it mobilized against it. The situation that had presented itself was the 1960's drought. The possibility of future shortfalls in water supply led water supply practitioners to study and to conclude that, based on their projections of future demands for water, metropolitan Boston risked a future water shortage. It was recommended that the Metropolitan District Commission, the agency responsible for the metropolitan Boston water supply, continue seeking upland sources further west of Boston and more specifically in the Connecticut River Basin.

Connecticut Valley residents felt that they were again being asked to divert additional water from their watershed to eastern Massachusetts. They initially opposed diversion of water from the Connecticut River on environmental grounds, but later found that they could argue more

effectively on managerial grounds. The approach changed the orientation of water resources planning, from the search for new sources in response to a drought and a projected water supply shortfall, to the consideration that water demand is also a variable. Demand management was employed to reduce water use and efforts were made to obtain reliable water use forecasts.

THE METROPOLITAN BOSTON WATER SYSTEM

The metropolitan Boston water system has evolved over the past approximately 340 years from collected rainwater and spring-fed sources in 1652, serving an estimated 5,000 people in the city of Boston, to a complex regional system consisting of reservoirs, transmission aqueducts and tunnels, and distribution storage facilities, etc. supplying approximately 2.5 million people in 31 fully supplied and 15 partially supplied communities. The expansion of the system responded to demands for pure water for Boston, which not only is the administrative capital of Massachusetts but also the commercial, industrial, institutional and cultural center for the surrounding communities. The expansion of the water system proceeded further and further west in the search for new and larger high quality supplies which did not require treatment and were capable of being gravity fed to the expanding service area. The system has extended westward to the Quabbin Reservoir some 65 miles from Boston, while previously used poorer quality sources were abandoned. The historic supplementation of supply to meet demand is depicted in Figure 1.

THE MASSACHUSETTS WATER RESOURCES AUTHORITY

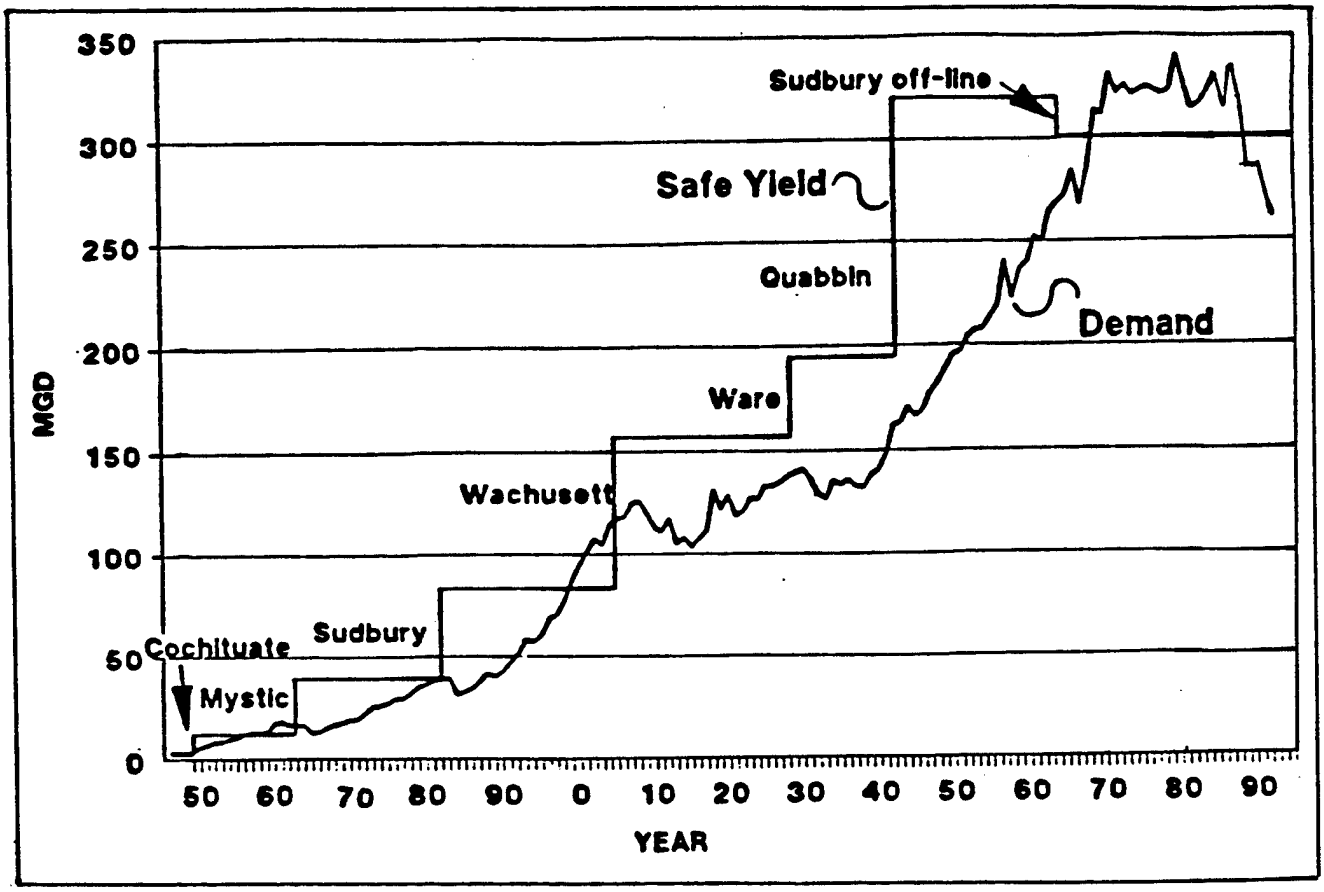
The Massachusetts Water Resources Authority (MWRA) was established in 1984 as an independent public authority with the mission to modernize the metropolitan area water and sewer systems and to improve water quality in Boston Harbor. It consists of a Water System and a Sewerage System and succeeded the Metropolitan District Commission (MDC) in all of these functions, except for the management of the watersheds and reservoirs, which was retained by the MDC in a newly created Division of Watershed Management. The MWRA provides wholesale water and/or sewer services to 60 Massachusetts communities. Twenty-nine communities receive or are entitled to receive both water and sewer services, 17 receive only water and 14 only sewer service.

The MWRA Sewerage System

The MWRA Sewerage System is maintained and operated to collect wastewater from 43 communities or approximately 2 million people in the metropolitan Boston area with more than 5,000 miles of local sewer pipes, and two treatment plants, that discharge into Boston Harbor.

Figure 1

METROPOLITAN BOSTON, MASS.
WATER SUPPLY AND DEMAND 1848-1992



Source: Massachusetts Water Resources Authority, MWRA Long Range WaterSupply Program, January 1990, p.7 and extended to 1992

The Sewer System is currently undergoing an 11-year effort to cleanup Boston Harbor by reducing the discharge of toxic chemicals into the system and wastewater into the harbor, renovating the pipes and pumping stations and constructing a new wastewater treatment plant and facilities. The court-ordered cleanup of Boston Harbor has been an issue in recent presidential campaigns and continues to be the major focus of MWRA activities.

The MWRA/MDC Water System

The MWRA/MDC Water System is managed to wholesale potable water to approximately 2.5 million people in 46 communities primarily in the greater Boston area or about 40 percent of the population in the Commonwealth of Massachusetts. The Water System is operated as a partnership with the Metropolitan District Commission (MDC) managing the watersheds and reservoirs and the MWRA with planning, managing and operating the remainder of the system including the transmission system, pumping and hydroelectric stations, and distribution reservoirs. All of the communities served are responsible for operating and maintaining their own distribution systems.

Figure 2 presents the principal structural components of the Water System. The water supply comes principally from the Quabbin and Wachusett Reservoirs located 65 and 32 miles respectively west of Boston. Water is diverted on a seasonal basis from the Ware River. During emergencies, water can be supplied from Sudbury Reservoir. The Quabbin Reservoir has a capacity of 412 billion gallons, which is approximately four years of supply at the current demand of approximately 260 mgd in 1992. The storage at Wachusett is 65 billion gallons. The over year storage at Quabbin Reservoir provides the system with a high level of reliability and allows it to exceed its safe yield, particularly during successive years of high precipitation. For planning purposes, the safe yield of the system has been estimated at 300 mgd. The implementation of drought management measures during deficit precipitation periods translates not only into maintaining higher levels at Quabbin Reservoir for the current period, but also the carry-over of conserved water into succeeding years. Contributions to the 300 mgd safe yield of the system are approximately 53, 33 and 14 percent each for the Quabbin, Wachusett and Ware River watersheds.

The Quabbin-Ware-Wachusett system not only has a vast storage capacity in relation to its drainage area and multiple year storage, but also the capability to deliver high quality water, without filtration, to member communities in a large metropolitan area of approximately 2.5 million consumers. With respect to compliance with the Safe Drinking Water Act, the MWRA and MDC have submitted an approved watershed resource protection plan for the Quabbin and

Ware River watersheds and has, therefore, succeeded for now in avoiding filtration of these water supplies for public water systems served by the MWRA. Regarding the poorer quality Wachusett source, the MWRA/MDC are committed to a dual track process. This process allows the MWRA/MDC time to develop alternatives to filtration such as watershed management while providing for the selection of a site, land purchase, an EIR, pilot testing, regulatory permits, and design and construction of a filtration plant at Wachusett Reservoir beginning in 1993 for construction in 2001. MWRA's goal is to demonstrate by July 1998 that the watershed protection plan has been successfully implemented resulting in improved water quality at Wachusett, thus obviating the need for a filtration plant at an estimated cost of $400 million. If a bypass were to be constructed allowing the delivery of Quabbin water to communities without passing through Wachusett Reservoir, and the relegation of Wachusett to reserve status, then the safe yield of the system would be reduced by one-third to about 200 mgd.

Water is transmitted by gravity beginning from a maximum elevation of 530 feet (BCB) at Quabbin Reservoir by the 13-foot diameter, 24.6 mile long Quabbin Aqueduct to Wachusett Reservoir. Seasonal supply enters the tunnel from the Ware River. Normally water from the Ware River flows by gravity for mixing and detention to Quabbin Reservoir. From Wachusett, water is delivered by a series of aqueducts and tunnels varying in diameter between 10 and 13 feet to feed fourteen distribution reservoirs or for direct delivery to community distribution systems. Average daily system use grew from 237 mgd in 1960 to 307 mgd in 1969 and remained above 300 mgd until 1988 after which it declined to less than 260 mgd in 1992. Maximum system use was 347 mgd in 1976 (See Figure 1). The recent decline in water use has been attributed to several factors including MWRA's adoption of a vigorous conservation program, the poor regional economic conditions and significant increases in the cost of water and sewer.

The historic low at Quabbin Reservoir was 44 percent full on 5 May 1967. Water restrictions were issued in 1966. Annual demand in 1965 was on the order of 278 mgd. Early in 1989 Quabbin Reservoir came under considerable stress thereby precipitating the declaration of water emergencies in Massachusetts communities and the preparation of drought management plans as required by the Water Management Act (1984). It registered approximately 68 percent full, compared to a 40 year average of 81 percent. Water use had been above the safe yield of the system since 1969. Water use was 323 mgd in 1988. During the previous four years precipitation had been below normal and the watershed yield had been significantly lower than the demand on the system. Out of concern for meeting future water demands, the MWRA is preparing an application of the Trigger Planning concept directed at initiating a procedure for ensuring the adequacy of future supply. This application is the subject of a separate report.

LAYOUT OF MWRA/MDC WATER SYSTEM

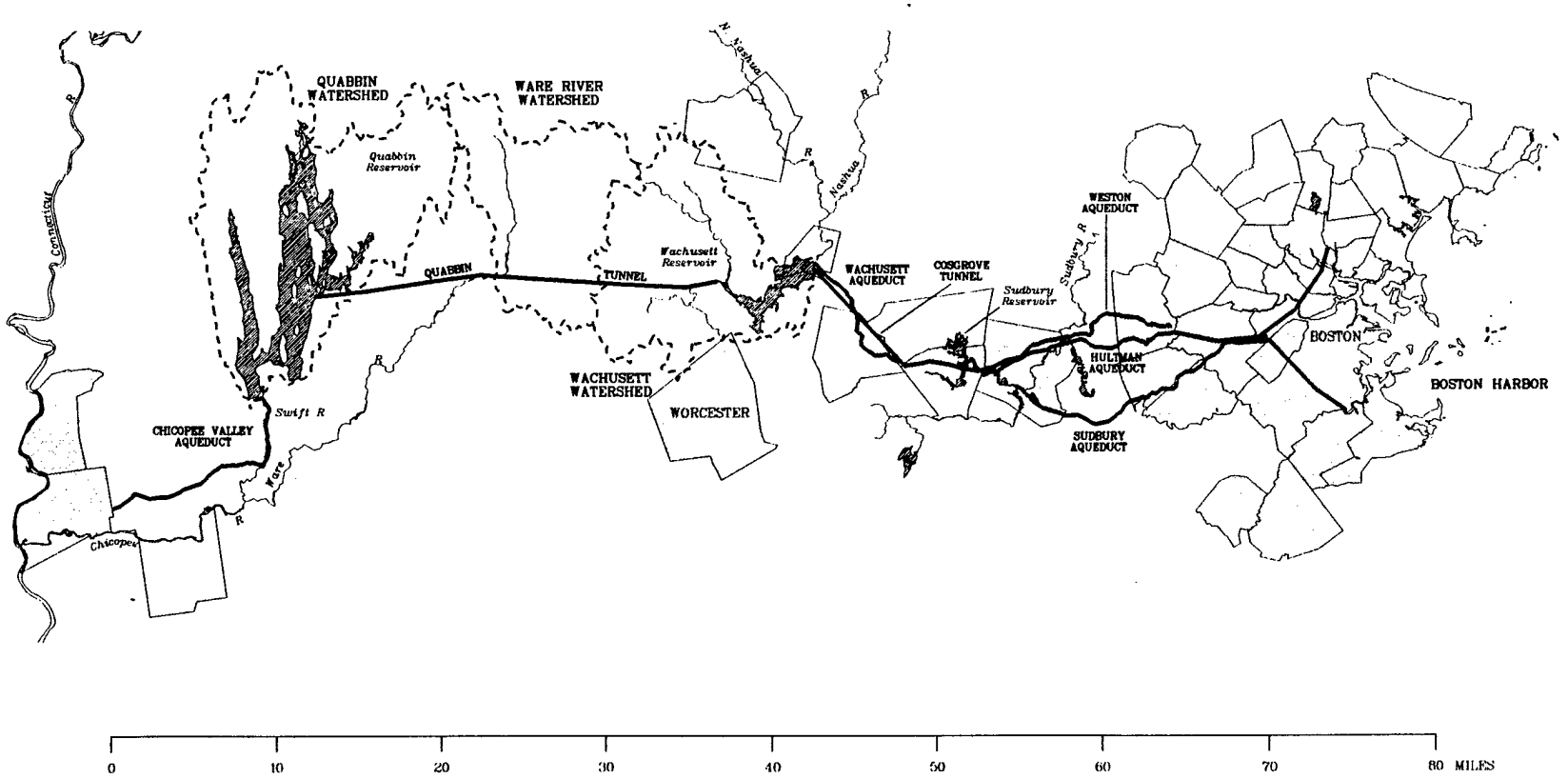


FIGURE 2

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Chapter 3
HISTORY OF WATER RESOURCES PLANNING IN THE BOSTON AREA

The history of water resources planning reveals the changes in the values upheld by those who influenced water supply planning. In Boston's approximately 360 year history, dominating influences first sprang from the individual citizen, who either supplied his/her own water or participated directly by voting on proposals for water system improvements and from health officials who established the relationship between potable water and good health. Later, city government was given responsibility for operating the water supply system. Water supply became one of the many functions of city government. Between approximately 1850 and 1960, those responsible for planning, developing and operating the Boston water supply system dominated the process. Since the 1960's, these same functions have been strongly influenced by citizens' groups from geographical areas in western Massachusetts where planners proposed to draw new supplies.

The 1960's drought in the northeastern part of the United States caused the level of Quabbin Reservoir to reach its historic low level of 44 percent full in May 1967. Managers of the system responded as they had done in the past by anticipating a future shortfall in supply. Supply augmentation from the Connecticut River became the preferred option to balancing projected demand and supply. However a coalition of citizens and citizens' groups, representing environmental interests, the academic community, planning agencies, and elected officials, organized to protect the resources of the Connecticut River Basin. This coalition eventually prevailed, thereby moving the Metropolitan District Commission (later in partnership with the Massachusetts Water Resources Authority) to adopt nonstructural solutions in response to anticipated shortfalls in the supply of water. Out of concern for being able to anticipate future water demands and respond in a timely way, the MWRA is utilizing a planning and management concept called Trigger Planning which initiates a data review and action program to ensure the adequacy of future supply. Trigger Planning is the object of a separate report.

This report examines the changes in water supply and management for the metropolitan Boston area over the past 360 years and more particularly since the 1960's. These changes have resulted in the movement from structural to nonstructural solutions to projected imbalances in supply and demand. A number of factors came together in our national, local and water resources cultures as well as advances in technology that shaped the values of the world and permitted these changes to take place. Agents of change or carriers of the new values mobilized to effect the changes.

Table 1 presents a chronology of the institutions responsible for the metropolitan Boston water supply and corresponding supply sources developed. Table 2 documents significant water resources planning events.

Table 1
DEVELOPMENT OF METROPOLITAN BOSTON WATER SYSTEM

Period	Institution	Primary Supply Sources	Safe Yield	Approximate Population	Conduits Built
1652-1795	Water Works Co.	Wells, Rainwater	-	5,000	-
1796-1846	Aqueduct Corp.	Jamaica Pond	-	19,000	-
1848-1875	Cochituate Water Board	Lake Cochituate Mystic Lake	18 mgd	175,000	Cochituate Aqueduct
1875-1895	Boston Water Board	Framing.Res.1,2,3 Lake Cochituate Mystic Lake	69 mgd	500,000	Sudbury Aqueduct
1895-1919	Metropolitan Water Board (and Sewerage Board - 1900)	Wachusett Reservoir Sudbury Reservoir Framing. Res. 1,2,3 Mystic Lake	160 mgd	1,000,000	Wachusett Aqueduct Weston Aqueduct
1926-1947	Metropolitan District Water Supply Commission	Quabbin Reservoir Ware River Wachusett Reservoir Sudbury Reservoir	320 mgd	1,500,000	Quabbin Tunnel Hultman Aqueduct
1947-1984 (also Aqueduct 1919-26) Tunnel	Metropolitan District Commission	Quabbin Reservoir Ware River Wachusett Reservoir Sudbury (off 1974)	300 mgd	2,500,000	City Tunnel Chicopee Valley Cosgrove City Tunnel Extension Dorchester Tunnel
1985 -	MWRA	Quabbin Reservoir Ware River Wachusett Reservoir	300 mgd	2,500,000	-

Note: Population figures are rough approximations for the period.
Source: Massachusetts Water Resources Authority, Twenty Year Waterworks Master Plan, July 1992, p.19.

Table 2

WATER RESOURCES PLANNING EXPERIENCE FOR THE METROPOLITAN BOSTON WATER SUPPLY SYSTEM

WATER SELF-SUPPLIED OR BY WATER COMPANIES

1630-1794: Sources of Supply from within the city.

- Boston supplied by water from sources within the city: wells, rainwater.

1795: Jamaica Pond.

- Jamaica Pond Aqueduct Company created to bring water from Jamaica Pond in what was the Town of Roxbury into Boston.

PURSUIT OF SOURCES FURTHER WEST OF BOSTON

1846: First U.S. publicly owned supply established.

- Massachusetts legislature authorized city of Boston to withdraw water from Lake Cochituate thereby establishing the nations first publicly owned water supply.

1848: Cochituate System.

- Cochituate System completed.

1870: Mystic Lakes.

- Mystic Lakes System, located north of Boston, added to the Boston system with the annexation of Charleston to Boston.

1872-98: Sudbury System.

- Sudbury, located 23 miles west of Boston, brought an additional 42 mgd to the safe yield of the Boston system.

FURTHER PURSUIT OF HIGH QUALITY, GRAVITY-FED, LOW MAINTENANCE STRUCTURAL SOURCES WEST OF BOSTON AND ABANDONMENT OF PREVIOUSLY USED SOURCES, REGIONALIZING OF THE WATER SYSTEM

1895: State board of Health Report.

- State Board of Health issues a report prepared by Frederic P. Sterns recommending the regionalizing of the greater Boston water supply system and the construction of the Wachusett Reservoir.

1908: Wachusett Reservoir.

- Wachusett Reservoir, located 32 miles west of Boston completed with an estimated safe yield of 105 mgd. Oversized aqueducts installed to permit the extension of the system further west.

1922: Joint Study.

- In 1919, the Massachusetts Legislature commissioned a joint study by the Metropolitan District Commission (MDC) and the State Board of Health of the water supply needs and alternating sources for the metropolitan Boston area. Henry Goodnough, Stearns' protege and successor at the Board of Health, proposed the Stearns plan: the addition of the Ware River and Quabbin Reservoir to the MDC system. In 1922, the Joint Board issued a report recommending the proposal.

Table 2 (continued)

1926-27: Ware and Swift Rivers.

- Ware River Supply Act and Swift River Act authorized the construction of works on the Ware and Swift Rivers leading to the extension of the MDC water supply to include the Ware River Intake and the Quabbin Reservoir. The choice therefore continued the tradition of favoring relatively maintenance-free solutions where the risk of human error could be avoided as opposed to the filtration of the Merrimack River or local sources in the Assabet/Ipswich/Sudbury systems.

1929-31: State of Connecticut Suit.

- State of Connecticut sued the Commonwealth of Massachusetts to enjoin the implementation of the Ware and Swift River Acts. Argued that lower flows in the Connecticut River would increase pollution, impair navigation, and diminish water power. The reduction in annual flooding and the fertilization of the banks and bottom lands would adversely affect agriculture. U.S. Supreme Court appointed master and Court found that there was insufficient evidence to show that substantial injury would result to the State of Connecticut.

1931: Ware River Intake.

- Ware River intake located about midway between Wachusett and the future Quabbin Reservoirs completed and connected to Wachusett Reservoir.

1939-46: Quabbin Reservoir.

- Quabbin Reservoir, located 65 miles west of Boston, completed in 1939 and after filling was on line in 1946. With a capacity of 412 billion gallons, it delivers high quality water by gravity eastward to Wachusett from where it is transmitted to the Boston area.

1961-67: Northeast Drought.

- Capacity of Quabbin Reservoir reduced to a historic low of 44 percent on 5 May 1967. Drought triggers concerns on the adequacy of the current sources of supply (Quabbin, Ware River and Wachusett watersheds).

1961-72: Studies for Northfield Mountain.

- Preliminary studies were initiated leading to the Northfield Mountain Project, a pumped-storage facility using water from the Connecticut River. Studies examined the possibility of providing for an eventual water supply function which would augment the MDC metropolitan Boston water system through the diversion of water from the Northfield Reservoir to the Quabbin Reservoir or the Northfield Diversion. Northfield Project went into service in 1972 equipped with an intake for the Northfield Diversion.

1964: Authority to study Millers River.

- MDC receives legislative authority to study Millers River Diversion to the Quabbin Reservoir (Acts of 1964,Chapter 606).

Table 2 (continued)

1966: Authority to study Northfield Diversion.

- MDC's legislative study authority broadened to include the Northfield Diversion (Acts of 1966, Chapter 439).

1967: Authority for Northfield Diversion.

- Legislation authorizes the Northfield Diversion (Acts of 1967, Chapter 669).

1967-75: NEWS Study.

- Northeastern United States Water Supply Study (NEWS) undertaken and completed by the Corps of Engineers. Two Connecticut River Basin diversions were considered: Northfield Mountain and Millers River in order to bring future projections of water supply and demand into balance.

1971: Secretary, Executive Office of Environmental Affairs.

- Governors of Massachusetts appoints the first Secretary, Executive Office of Environmental Affairs.

WATER MANAGEMENT ERA BEGINS: DEMAND AS WELL AS SUPPLY CAN BE MANAGED TO ADDRESS POTENTIAL SUPPLY SHORTFALLS

1975: Curran Study.

- Curran Associates, Metropolitan District Commission Water Usage Study, University of Massachusetts Water Resources Center, Amherst, Mass. Study concluded the presence of significance unaccounted water in the MDC system due to leakage in transmission and distribution systems. Opponents to diversion argued that the detection and repair of the leaks would obviate the need for new sources.

1977: Massachusetts Water Supply Policy Study, Northfield Diversion declared a "major and complicated project"; NCAC established.

- Wallace, Floyd, Associates, Inc., Massachusetts Water Supply Policy Study concluded that water conservation, improved watershed management and the Northfield Diversion appear to be the least environmentally disruptive and cost effective solutions to MDC's predicted imbalance water supply shortfall. Also recommended that the MDC undertake a draft environmental impact report (EIR) on the Northfield Diversion.
- Mass. Secretary of Environmental Affairs declares the proposed Northfield Diversion a "major and complicated project" and decides that the MDC should prepare an EIR on the Northfield proposal under the Massachusetts Environmental Policy Act (MEPA).
- Northfield Citizens Advisory Committee (NCAC) established via a Memorandum of Understanding (MOU) signed by the Massachusetts Secretary of Environmental Affairs, the MDC and the Massachusetts Steering Committee on the Connecticut River representing a coalition of experts, environmental groups, and public officials with a focus on the Connecticut River. NCAC charged with providing a full advisory role in the preparation and review of the Northfield Diversion EIR.

Table 2 (continued)

1980- 86: MWRA/MDC Water Supply Study and Environmental Impact Report.

- Wallace, Floyd, Associates, Inc., starts MWRA/MDC Water Supply Study and Environmental Impact Report, which was issued in March 1986.
- 1980: Supply augmentation alternatives broadened, NCAC renamed WSCAC.
- Meanwhile, NCAC insists that all reasonable alternatives, both structural and nonstructural (no action, Connecticut, Merrimack and Upper Sudbury Basins, Plymouth Aquifer, watershed management, demand management and desalination), be given equal consideration. Study renamed Phase I - Long Range Water Supply Study (LRWSS). NCAC broadened to include participants representing the interests associated with the alternatives and renamed Water Supply Citizens Advisory Committee (WSCAC).

1983: Interbasin Transfer Act.

- Interbasin Transfer Act adopted (Chapter 658). The Act aims to regulate the transfer of surface and groundwater and including wastewater from one basin to another.

1985: MWRA operational, Massachusetts Water Management Act.

- MWRA established (1984 Acts, Chapter 372) as an independent and financially autonomous public authority to provide water supply and sewerage services to the areas of the Commonwealth served by the MDC. Assumed responsibility for the LRWSS and becomes operational in 1985.
- Establishment of the Massachusetts Water Management Act (Chapter 592). The Act empowers the Department of Environmental Protection to regulate the withdrawal of surface and groundwater in the Commonwealth and to be responsible for responding to potential water supply shortages and for declaring water supply emergencies.

1986: MWRA Water Supply Policy Statement.

- MWRA Water Supply Policy Statement (November 1986),issued by the MWRA Board of Directors and based on the results of the LRWSS established a series of policies adopting nonstructural solutions (demand management, improved watershed management) and the development of local sources as a means of balancing the demand and supply for water in the future. The development of new sources of supply is one of last resort. Board will not review any river diversion option until after 31 December 1989 at the earliest.

1990: MWRA Long Range Water Supply Program.

- MWRA Long Range Water Supply Program (LRWSP), Program Briefing and Recommendations to the Board of Directors (24 January 1990) recommends that the Board postpone their decision on the development of a new supply until 1995 at the earliest. Meanwhile, the MWRA would pursue its program of demand management, improved use of existing and new local sources, source protection and management and planning initiatives, including Trigger Planning (Part II of this report) and provide annual updates.

Table 2 (continued)

- Phase II Report, MDC-MWRA Long Range Water Supply Study and Environmental Impact Report - 2020 issued by MWRA in October 1990. Report closes out the MEPA process begun in 1980.

1991: MWRA Long Range Water Supply Program.

- MWRA Long Range Water Supply Program-Progress Briefing (12 June 1991), an annual update of the MWRA LRWSP. No action on a major new source was recommended.

1992: MWRA Long Range Water Supply Program; Watershed Protection Act.

- MWRA Long Range Water Supply Program-Progress Briefing(21 October 1992), an annual update of the MWRA LRWSP. Concluded that no immediate action on supply augmentation is required by the MWRA. Expressed satisfaction with the progress of the Corps of Engineers assisted Trigger Planning activity to provide the analytical tools to keep water supply and demand in balance.
- The Watershed Protection Act, which became effective in August 1992, is a state of Massachusetts response to the Safe Drinking Water Act. Its purpose is to conceive a scheme to regulate land use and activities of state watersheds, including MDC's Quabbin and Wachusetts watersheds, in order to prevent pollution of surface water sources.

1993: Twenty Year Waterworks Master Plan (1993-2012).

- Master Plan details a capital investment program over the period 1993-2012 with respect to repairing and restoring the MWRA/MDC Water System and to meeting higher water quality standards. The plan includes 120 projects with an estimated cost of approximately $1.9 billion. Nearly one-third of these projects are already approved on MWRA's FY 92-94 Capital Improvement Program.

Source: The New England Drought Study on the basis of information provided by MWRA Waterworks Division.

PLANNING 1630 TO 1850's

Since the time of the first settlement, Boston's citizens used wells, constructed cisterns, and collected rainwater to provide for their water supply needs. In 1795, the system gradually moved westward within present city limits as the Jamaica Pond Aqueduct Company developed Jamaica Pond to carry water through three and four inch log pipes into the city. Beginning in the 1830's, an increasing population with increased individual water supply needs began to look towards less densely populated areas west of Boston and particularly to Long Pond in Wayland. Meanwhile, in 1850 Lemuel Shattuck demonstrated that disease and mortality rates were far worse in densely populated cities due to unclean streets and poor sewage disposal. (1) His studies advocated pure and abundant water for urban populations and led to the creation of the Massachusetts Board of Health in 1869. The search for pure and abundant water, not requiring treatment, would underpin municipal and industrial water supply decisions for the metropolitan Boston area for the next century.

During this period, individual citizens participated directly in matters of water supply by voting on proposals for system improvements. The water supply planning process would remain a popular issue until the arrival of John Jervis in Boston in 1846. With no formal engineering education, he was both a product and propagator of the apprenticeship system in which more experienced engineers provided on-the-job training for new recruits. Between 1816-27, Jervis progressed from axman to chief engineer in the construction of the Erie Canal in New York. He later established a reputation in the design of the New York City water system and went on to become America's foremost water supply engineer. (2)

Hired as a consulting engineer by the City of Boston, Jervis reviewed plans to expand the system to Long Pond in Wayland, later renamed Lake Cochituate, and recommended the adoption of the plan by the Water Board. After the Lake Cochituate extension to the Boston Water Supply in 1848, the Water Board established Boston as the nation's first publicly owned water supply system. In 1851, the Boston City Council delegated responsibility for the operation of the Boston water supply to the Water Board. "From that time forward, it was the experts who controlled the system, monitoring all questions of demand and supply. What had been a popular, political issue became a technical issue initiated by an administrative request to the General Court for permission to add to the water supply system." (3) From 1795 onwards, water supply planners started a trend that was to continue well into the twentieth century. As deficits were anticipated for the Boston water system, new, pure upland sources were sought in sparsely settled areas farther and farther into western Massachusetts. If there were donor basin politics, practiced by those representing geographical areas from which the augmentation of supplies would be taken, they were not manifest at this time.

PLANNING 1850's to 1960's

Between approximately 1850 and the 1960's, the decisions on municipal and industrial water supply expansions were conditioned by society's conviction that pure and abundant supply of water promotes health and on how engineers proposed to fulfill these needs. The values of the water supply engineers were shaped by the apprenticeship system in which newcomers were proteges of their supervisory mentors. Parallel to this system, more formally trained engineers were beginning to graduate from the U.S. Military Academy established in 1802. After 1850, civilian engineering schools or facilities were established and by 1870, 21 such facilities had been created. See attachment A. However, the planning of improvements for the metropolitan Boston water supply was influenced by the apprenticeship system possibly until as recently as the 1960's.

> "The transformation of the water supply from a mobilizing political issue to an area of expertise for competent professionals was abetted by the respect Bostonians had for their water supply engineers. Engineers were the geniuses of the age. By their unique ability to harness technology, they changed the fabric of nineteenth-century life designing and building, among other things, railroads, canals, telegraph systems, tunnels, harbor improvements, steam engines and bridges. Engineers transformed society, reshaping the environment and reducing dependence upon manual labor." (4)
>
> "The engineers' successful battle with the dangers to public health was even more impressive. Public health was a dominant issue in Massachusetts in the nineteenth century; the sanitary and water supply engineers were entrusted with the responsibility for (and credit with) protecting it." (5)

In 1898, the seven reservoir Sudbury System, located some 23 miles west of Boston, and consisting of seven reservoirs on the north and south branches of the Sudbury River, was completed and added to the Boston water system. The names of two engineers, one a mentor to the other, have been associated with the subsequent major expansions to the Boston water supply system. Like Jervis, Frederic P. Stearns, became an engineer through the apprenticeship system. Having built a solid municipal engineering reputation by fathering such notable projects as the construction of the dam and tidal lock on the lower Charles River between Boston and Cambridge, he became the Chief engineer in 1886 for the recently created State Board of Health. As such he filed the Board's response on February 1, 1895 to the General Court's passage of "An Act Relative to Procuring in Water Supply for the City of Boston and It's Suburbs". (6) In the preparation of the report he considered new sources at Lake Winnipesaukee, which was too expensive and unlikely that the state of New Hampshire would agree to the plan, in addition to the Merrimack and Nashua Rivers. For the Merrimack the cost of transmission and filtration

were reasonable. However, filtration was not desirable because it required "continuous care on the part of well-trained attendants". (7) "Stearns agreed that the Merrimack plan would cost less, but he remained firm in his opposition to this alternative, citing the need for filtration and pumping as his two major objections." (8) Stearns said, however, that he was more easily led "to reject the filtered waters of the polluted Merrimack because he had found an entirely satisfactory source thirty-two miles west of Boston." (9) The report recommended the construction of the Wachusett Reservoir in Clinton, Massachusetts on the Nashua River, some 32 miles west of Boston thereby creating a reservoir holding 65 billion gallons of water. The Wachusett Reservoir was completed in 1908 as a regional water supply. The Wachusett system was recognized as a great engineering achievement and won a gold medal at the 1900 Paris Exposition. The American Society of Civil Engineers bestowed on Stearns its highest praise.

> "It may justly be said that...the complete system of water supply for the city of Boston and the...surrounding municipalities comprising great and noble dams in masonry and earth reservoirs, aqueducts, pumping stations, and pipe systems...were conceived with foresight and executed with skill guided by the hand of nature herself...They (were) at the date of their construction probably the most noteworthy series of water works structures in the United States foremost not altogether in size, but in perfection of detail and the embodiment of the best practice of hydraulic engineering throughout." (10)

The 1895 report also pointed the way for the future expansion of the system's water supply capacity to the Ware and Swift Rivers, tributaries to the Connecticut River. Stearns' legacy consisted not only of the planning and construction of the Wachusett Reservoir but also the introduction of the Ware River Intake and Quabbin Reservoir as possible future sources, and the provision of an oversized aqueduct from Wachusett eastward towards Boston to permit system expansion to the west. Also,the region inherited a Stearns' protege, in the person of Henry Goodnough, who would shepherd the Quabbin/Ware River proposal through to construction.

Meanwhile the Board of Health's estimates of future population and per capita water use led to a substantial increases in projected total water use for the system. The Board found that per capita water use in the communities served by the metropolitan Boston water supply was 83 gallons per day in 1893 and estimated that this would rise to 100 gallons per capita per day (gpcd) in 1920 and remain at that level until 1930. However per capita use grew to 127 gpcd in 1907, but declined due to the widespread use of metering. In that year a law was passed requiring universal metering. Between 1907 and 1915 per capita water use fell to 95 gpcd and remained under 100 gpcd to the early 1940's. (11)

With respect to unaccounted for water and leakage, efforts at leak detection and repair in Boston's Charlestown area were promising. In 1880, the installation of Deacon meters in water mains permitted the detection of significant leakage in the system, the repair of which resulted in a drop in per capita use of 22 percent from 1883 to 1884. The extension of leak detection and repairing to a greater part of the city saw a decrease in per capita use from about 92 to 71 gpcd. From this program, it was estimated that 15 gpcd of leakage or about 15 percent of demand was unavoidable and leakage above this amount was preventable. (12)

By 1918, the Metropolitan Water and Sewerage Board considered the expansion of its water supply. At the same time the city of Worcester, located in western Massachusetts near the Wachusett Reservoir, petitioned the General Court for authorization to draft a plan for meeting its future water needs. The General Court appointed a Joint Board comprised of the Metropolitan Water and Sewerage Board and the State Board of Health to undertake the appropriate studies. As chief engineer for the State Board of Health and successor to and protege of Stearns, Henry Goodnough, was chosen to lead the investigation. Born in Brookline, Massachusetts he graduated from Harvard College in 1882. His formal education set him apart from his two notable predecessors in the Boston water supply community. His analysis of metropolitan Boston's water needs caused him to reach conclusions that were similar to those of his predecessor, Stearns.

The Joint Board submitted its report in 1922 recommending the extension of the water system to the Ware and Swift Rivers. In so doing it remained somewhat faithful to earlier recommendations of the Board of Health's 1895 report with one important modification. The 1922 report argued that instead of diverting full flows of these two rivers, only the flood flows from the Ware River and all but a minimum flow from the Swift River would be used for augmenting Boston's water supply, thus preserving supply for navigation, and reducing damaging flood flows for industry (Ware River). The arguments of the Joint Board and Goodnough were similar to those used to advance the construction of Wachusett Reservoir: the search for gravity-fed pure supplies that did not require filtration; and the abandonment or relegation to backup status of previously used, generally poorer quality, water supplies. In addition, the proposal was a logical extension of the earlier decisions to construct Wachusett.

The proposal was opposed by a number of interests including the eminent engineer, Alan Hazen. He, along with Hiram Mills, had pioneered filtration experiments on the Merrimack River, located north of Boston. Although Hazen endorsed the Wachusett Reservoir as the most sensible at the time (13), he felt that the technology of water filtration had advanced sufficiently to warrant consideration for system expansion. He counter-proposed that eastern sources should

be filtered and used. The four communities which would be flooded from the filling of Quabbin Reservoir opposed the expansion of the water system into the Swift and Ware Rivers, but because they sought an early resolution to the issue of constructing Quabbin regardless of the outcome, they weakened their opposition to it. Potential opposition from industries in the Swift and Ware River Basins to Quabbin Reservoir, was also weakened with the provision of compensatory reservoirs to industries in the plan. (14) Eastern Massachusetts industry was very likely uneasy about the Hazen proposal since the focus of the supply augmentation would be on resources that they were enjoying with few restrictions.

As a riparian state, Connecticut claimed the right to the undiminished flow of the Connecticut River. In 1929, Connecticut filed suit against the Commonwealth of Massachusetts alleging that any subtraction in flow from the Connecticut River would cause serious harm to the State of Connecticut by impairing the river's navigability, diminishing power capacity, lessening the agricultural production of the river's bottom lands and lessening its ability to dilute sewage. On the basis of a court appointed master's report, in 1931 the U.S. Supreme Court found that there was insufficient evidence to show that substantial injury would result to the State of Connecticut from the diversion of flow from the Swift and Ware Rivers in accordance with the quantities authorized by the acts of 1926 and 1927, as heretofore limited by the War Department. The suit was dismissed without prejudice to the right of the State of Connecticut to maintain a future suit against Massachusetts should interests in Connecticut face injury through a material increase in the amount of water diverted from the Swift and Ware Rivers above those authorized by the acts. (15) This was the first time that arguments based on the potential harm to the ecology of the source and related lands were advanced to stop the development of a supply source.

The Ware River Intake was completed and connected to the Wachusett Reservoir in 1931. It has no storage. The Quabbin Reservoir was completed in 1939. It took seven years to fill and was brought on line in 1946. Quabbin is located on the Swift River some 65 miles west of Boston. With a storage capacity of 412 billion gallons, it is one of the world's largest water supply reservoirs. High quality untreated water is conveyed by gravity eastward past the Ware River Intake into Wachusett Reservoir and then on to Boston.

The conditions and values that influenced the nature of the development of the metropolitan Boston water system from 1850 to 1960 were:

- Society's acceptance of the health community's finding that abundant supplies of pure water would improve health conditions.

- Planning and development of water supply systems left largely to municipal engineers. Engineers were trained to design and construct civil works in response to potential water shortages. Potential imbalances in supply and demand were addressed by increasing pure gravity-fed supplies.

- Metering and leak detection and repair was found to be effective in reducing unaccounted water in the metropolitan Boston water supply system. No consideration was given to moderating consumer demand.

- No formally trained non-Military U.S. water supply engineers at the beginning of the period. Later engineering schools and facilities were beginning to be established in the U.S. Apprenticeship system was in place but gradually it began to coexist with that of formally trained engineers. Apprenticeship system relied on mentor/protege relationship, with its tendency to limit innovation for those more likely to promote innovation: the new recruits to water system design, management and operation.

- At the beginning of the period, municipal water supply planners were partial to projects requiring limited operational expertise. The need for skilled personnel in the nineteenth and early twentieth centuries may have contributed to such an approach which favors projects developed in pristine areas drawing on pure gravity-fed water requiring no filtration, use of sources west of Boston, abandonment of sources in eastern Massachusetts and the implementation of large scale projects to take advantage of economies of scale.

- Manufacturing which depends on water for power, processing, cooling and dilution assumed a significant place in the New England economy and peaked during the first half of twentieth century. Industrial needs were factors in water supply planning and were taken into account by water resources planners. As the manufacturing industry began to wane so did its importance in the water resources planning process. Industry was enjoying virtual unrestricted use of rivers for supply and waste discharge. Filtration of local water sources in urbanized areas was avoided partially in deference to industry.

- Municipal water supply planners recognized the significance of industry to the Massachusetts economy and addressed some of their concerns in the development of new supplies. Metropolitan Boston area citizens were generally satisfied with cheap and abundant pure water provided by municipal engineers. Citizens and their public representatives from communities due to be flooded or otherwise adversely affected by the proposed reservoirs at Wachusett and Quabbin opposed these projects but were unable to prevail. There was likely limited input from local citizens in the formulation of the two projects. The U.S. Supreme Court found that there was insufficient evidence to show that substantial injury would result to the State of Connecticut from the diversions from the Connecticut River Basin, as authorized by the Massachusetts Acts of 1926 and 1927, and limited by the Secretary of War, (15) thus permitting the construction of Quabbin Reservoir.

PLANNING 1960's TO PRESENT

Beginning in the 1960's, private citizens and citizens' groups began to intervene more effectively in the planning and development of the metropolitan Boston water supply system. They came with values that they wanted included in the water resources planning process. Water system managers, as well as individual citizens and citizens' groups, were being shaped by events and significant changes in societal values.

The 1945-1968 period in the United States saw a rapidly expanding population and economy as a result of the removal of wartime restrictions and the pent up demand for goods and services. The national economy was able to foster higher standards of living for the expanding population while permitting the pursuit of social ideals such as civil rights, etc. But the 1960's was the last decade to see a sustained rise in both income and income equality. (16)

Beginning about 1968 the U.S. economy experienced a leveling off of economic growth. The profound changes in American culture became apparent. "Thus, American culture began to look away from public and political solutions to problems - an emphasis that had prevailed since the end of World War II." (17)

The nation experienced, primarily among the young, a suspicion of the values of society and their translation into everyday life. They protested against the established values. The generation gap was a reality. The so-called "establishment", or those in power, was suspect. These included the government, politicians, educators, parents, experts, etc. A counterculture emerged which defined itself in terms of life-style, hairstyle, dress, living arrangements, and the espousal of certain causes, such as peace and respect for the environment. They spearheaded individual citizen involvement to change society. One of their legacies is that people today, while relying on expert advice, are more likely to take more direct responsibility for important decisions in their lives.

At this time three presidents, who portrayed themselves as outsiders to the Washington decision-making scene were elected: Nixon, 1969-74; Carter, 1977-81; and Reagan, 1981-89. The environmental movement, which began much earlier, was firmly established with the passage of the National Environmental Protection Act (NEPA) in 1969 and the Federal Clean Water Act and Massachusetts Environmental Policy Act (MEPA) in 1972.

The 1960's drought in northeastern United States and the institutional responses to it set the stage for a conflict between the operators of the metropolitan Boston water supply system and

those who initially opposed but later wanted to participate in its planning process. The drought triggered a concern among system operators that the current supply might not be adequate for satisfying future demand. The Metropolitan District Commission (MDC), was responsible for the operation of the metropolitan Boston water supply and sewerage system at this time. Operators of the system chose to pursue supply augmentation to address the projected imbalance of future demand versus supply.

The Northfield Diversion was the preferred choice of the MDC for supply augmentation, one of the proposals supported by the Corps of Engineers in its Northeastern United States Water Supply Study - Summary Report, July 1977 (NEWS) to draw additional supply from the Connecticut River Basin, and supported by the newly created Executive Office of Environmental Affairs (EOEA) in 1973 until a later reversal of this position. In addition, the 1977 report, Massachusetts Water Supply Study, Wallace, Floyd Associates, Inc. supported the diversion. The Northfield Diversion would piggyback on a proposal for a pumped storage facility to generate hydroelectric power from the Connecticut River at Northfield Mountain, which was completed in 1972. In anticipation of serving the MDC, the Northfield Mountain project was provided with a higher capacity reservoir and equipped with an intake that would permit the skimming of flood flows from the Connecticut River, temporary storage in the reservoir and conveyance to Quabbin Reservoir for service to the metropolitan Boston area.

Citizens and citizens' groups representing environmental interests, the academic community, water users, and planning agencies and elected officials from the Connecticut River Valley in western Massachusetts were opposed to proposals to resolve a predicted water supply shortfall in metropolitan Boston through withdrawals from the Connecticut River Basin. Opponents had a youthful, highly motivated, environmentally conscious cast with links to the Springfield Conservation and the New England River Basins Commissions and backup from the academic community in the area. They were centered in the Connecticut Valley in Massachusetts and south of the proposed Northfield Mountain Project. They argued that equity demanded that metropolitan Boston curb its appetite for new sources by managing its own system more efficiently (leak detection and repair, domestic device retrofitting, etc.) before setting its sights on new sources in the Connecticut Valley. They also argued that the proposed diversion would be harmful to the ecology of the Connecticut River Valley.

Although research demonstrated that the majority of valley residents did not share these views and in fact were not opposed to the Northfield Diversion, the opponents, according to Kaynor "while relatively few in number, those opposed have been vigorous, dedicated, and were more knowledgeable than proponents". (18) The opposition was reborn in successive groupings

beginning with the Connecticut River Information Clearinghouse (CRACK) in 1969, the Connecticut River Ecology Action Corporation (CREAC) in 1971, etc. to the form it enjoys today, the Water Supply Citizens Advisory Committee (WSCAC). WSCAC succeeded the Northfield Citizens Advisory Committee (NCAC) which was created in 1977 at the time that the Secretary, EOEA declared the Northfield Diversion, a "major and complicated project" requiring an Environmental Impact Report (EIR) in accordance with Massachusetts Environmental Policy Act (MEPA) regulations. The NCAC was established via a Memorandum of Understanding (MOU) signed by the Secretary, EOEA, the MDC and the Massachusetts Steering Committee on the Connecticut River. The NCAC, comprised mainly of members from the Connecticut Valley interests, was given a full advisory role in the preparation of the EIR. As the number of solutions to metropolitan Boston's projected water supply deficit widened to include other alternatives, WSCAC was created in 1980 to succeed the NCAC and represent a wider range of views according to geographical areas and functions that were related to these alternatives.

It has been said that WSCAC has been successful in using the competence, commitment and connections of its members to influence the EOEA, to steer the MDC to consider more options for solving metropolitan Boston's water supply imbalance including supply and demand management, and to re-examine demand projections. According to WSCAC, its members played a significant role in the passage of the Interbasin Transfer Act, the Water Management Act and the creation of the MWRA itself in 1984.

The MWRA/MDC water system managers were among the first in the nation to respond positively to the demands of the evolving culture which was calling for more public participation in the planning and management of water supply systems. Although somewhat reluctant initially, system managers were persuaded to take the steps and mobilize the necessary resources that acknowledged public input into the planning and management process. These steps led to the establishment of the MWRA and the adoption of nonstructural measures to ensure future adequacy of supply such as demand management (leak detection and repair, retrofit program, flow metering and monitoring, protection of local sources, etc.), the Long Range Water Supply Program, etc..

The MWRA was established in 1984 as an independent and financially autonomous public authority. In 1985 it assumed responsibility from the MDC for the delivery and distribution of water in 46 communities primarily located in the metropolitan Boston area as well as sewerage services for the MDC. The MDC, which was responsible for water supply and sewerage services since its creation in 1919, retained responsibility for the management of the watersheds and reservoirs. The financial autonomy of the MWRA contrasts sharply with the MDC. The

MDC was required to request funding on an annual basis from the Massachusetts legislature and to deposit revenues collected from the sale of water into a general fund. The result had been a legislature not inclined to provide the funds for the adequate maintenance and improvement of the system and a wholesale municipal and industrial (M&I) supplier its own funds to execute these responsibilities. The water system inherited by the MWRA was in dire need of capital improvement because of deferred maintenance.

Chapter 4
DROUGHT RESPONSE

The most severe and prolonged droughts in New England during the twentieth century occurred during the following periods.

1905-14: most severe in accumulative precipitation deficits and confined generally to Maine.

1930-32: severe low precipitation runoff, except Maine.

1961-67: Severe and prolonged low precipitation runoff especially in southwest New England, but of shorter duration in Maine.

Other less severe droughts occurred in New England in 1921, 1941-1942, 1948-1950 and 1957.

The description of the metropolitan Boston water supply system's response to drought, since Quabbin Reservoir was completed in the 1930's, is based on information provided by the Massachusetts Department of Environmental Protection and the MWRA. (19) During this period the MWRA /MDC Water System has experienced only one major drought, that of the 1960's. Periods of low precipitation occurred, however, in 1981, 1985, and 1989, but did not develop into significant droughts.

Quabbin Reservoir reached its historic low of 44 percent full on 5 May 1967. Meanwhile the MDC requested outdoor restrictions for six weeks in 1966 after Quabbin reached 65 percent capacity on 11 August 1965. No serious attempts at demand management, or measures to reduce demand on a long term basis, were attempted at this time. System water use was on the order of 280 mgd. The drought caused the MDC to consider the adequacy of long term supply and to later conclude, on the basis of projected demand, that supply would not be adequate and that supply augmentation should be pursued.

In 1981, the Secretary of Environmental Affairs reacted to a short dry period by establishing the Drought Management Task Force and the MDC prepared a broad framework for drought response. The control levels proposed by MDC at this time were:

Normal Operation - 80 to 100 % full
Drought Watch - 65 to 90 % full
Drought Warning - 50 to 75 % full
Drought Emergency - < 60 % full

In addition, the minimum pool at Quabbin was set at 490 feet or 38 percent full. As the level dropped to "Drought Watch", requests for voluntary conservation and public education were initiated. By 1981, system demand increased above the safe yield of 300 mgd to 328 mgd. Meanwhile above normal precipitation returned making it unnecessary to consider further action. The Water Management Era was initiated with issuance of the Curran Report in 1975, which identified significant unaccounted water in the system. The report was followed by a series of studies leading to the MWRA Water supply Policy Statement in November 1986 adopting a series of non-structural measures as a first step in ensuring future supply adequacy, including a review of the drought management program, and declaring that the development of large new, especially out-of-basin source development, was one of last resort. In May 1985, the MDC again issued a "Drought Watch" for the system and initiated requests for voluntary conservation. Although the public was advised that subsequent drought control levels would involve outdoor restrictions, precipitation in 1982 to 1985 was above normal and supply shortages were avoided.

Meanwhile, with the assistance of a consultant and by working through a state interagency committee, MWRA and MDC began the preparation of a Drought Management Plan for the system again using Quabbin Reservoir levels for indicating timely drought management. The onset of a possible water shortages in early 1989 accelerated the completion of the plan, which was submitted to DEP for review in April and finalized in June 1989. Figure 3 and Table 3 respectively present the MWRA/MDC Drought Status Control Diagram and the Target Use Reductions and Response Activities.

In early 1989, after two years of below average precipitation and continued, but declining, demand on the system above its safe yield, Quabbin Reservoir registered a level at 68 percent full compared to a 40 year average of 81 percent for that time of the year. The system was therefore in the Drought Warning stage and the Massachusetts Drought Management Task Force was reactivated. Soon after the drought was declared, precipitation was above average and the reservoir rebounded to nearly 72 percent full by 24 April 1989 and to 75 percent by late June. By 16 August 1989, DEP had declared the end of the emergency. System water use dropped from 323 mgd in 1988 to 285 mgd in 1989. The MWRA attributes about 15 mgd of the nearly 40 mgd decline to cooperative weather and drought conservation.

Table 3
MWRA/MDC DROUGHT MANAGEMENT PLAN
TARGET USE REDUCTIONS AND MWRA RESPONSE ACTIVITIES

Trigger Range Stage	Target Water Use (Quabbin % Full)	MWRA Reduction	Response Measures
Normal Operation	80 - 100	0	
Below Normal	65 - 90	Previous year's system use	- Advise local officials and media - Distribute MWRA materials - Repair leaks - Rehabilitate meters
Drought Warning	50 - 75	5%	- Identify drought coordinator - Restrict outdoor and municipal use - Request voluntary cuts from large users and visible users (car washes, restaurants, etc.) - Initiate Water Bank - Enforcement:fines
Drought Emergency			
Stage 1	38 - 60	10%	- Ban nonessential outdoor, municipal water use - Request more large user cutbacks - Distribute new materials - Continue coordination local actions - Consider rate structure changes
Stage 2	25 - 38	15%	- Increase meter reading frequency - Establish mandatory rationing and enforcement - Distribute info materials and feedback on savings - Modify rate structures - Moratorium on new connections
Stage 3	Below 25	30%	- Revise rationing for 30% reduction - Continue distribution of materials, organization of local response - implement emergency sources or interconnections

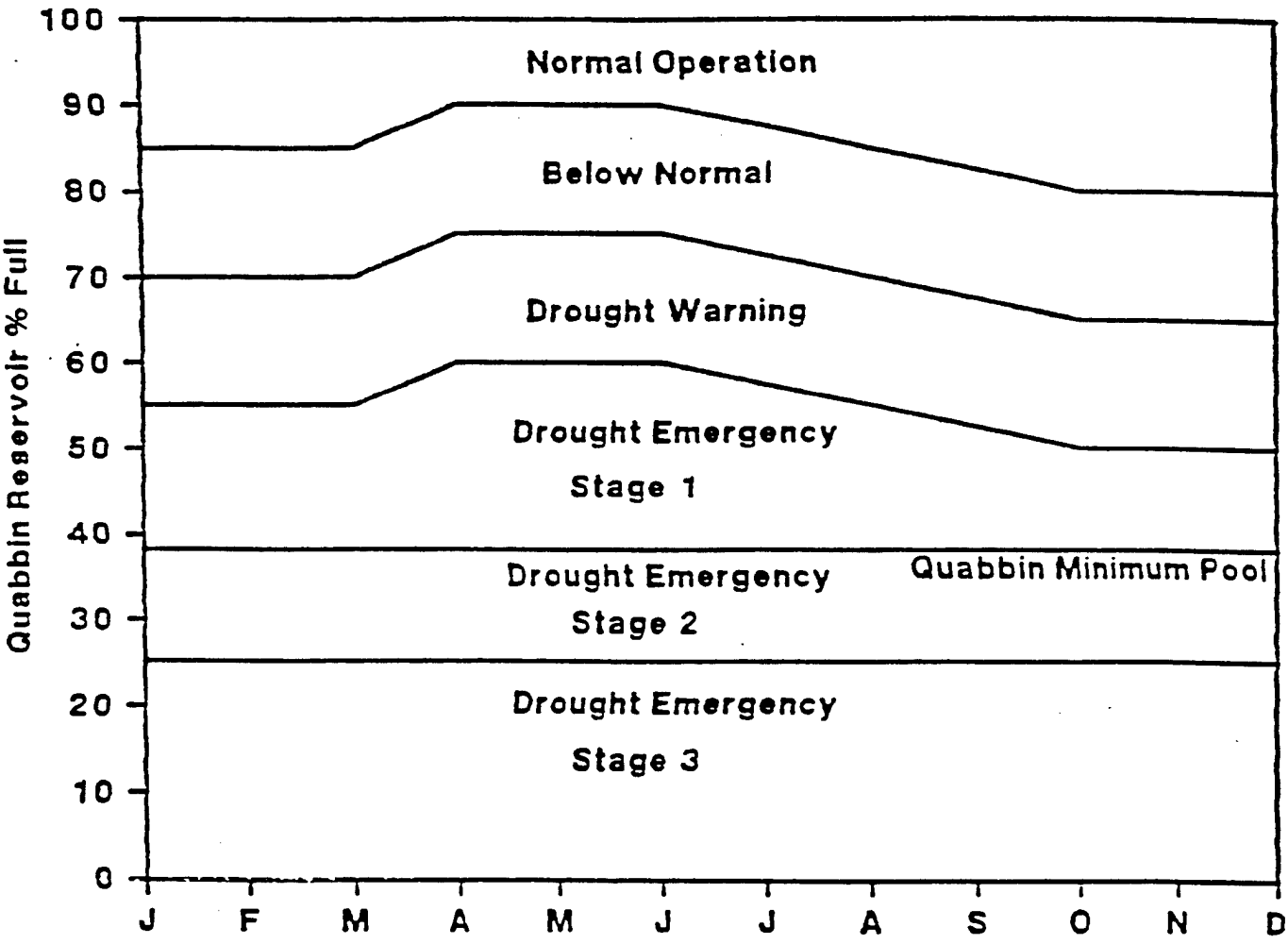
SOURCE: MWRA, Drought Management Plan, undated.

Figure 3

The New England Drought Study

Massachusetts Water Resources Authority \ Metropolitan District Commission
Drought Management Plan

DROUGHT STATUS CONTROL DIAGRAM
TRIGGER LEVELS AT QUABBIN RESERVOIR



Source: MWRA, Drought Management Plan, undated, p. 5-4.

Chapter 5
CURRENT METROPOLITAN BOSTON WATER SUPPLY PLANNING

RECENT DECLINE IN WATER USE

According to the MWRA's Waterworks Division, the recent decline in system water use from 334 mgd in 1987 to 257 mgd in 1992 is attributable to three factors:

- demand management,
- the cost to consumers of water and sewer services or water services,
- the changing and depressed economy.

A detailed analysis attributing portions of these three factors to the decline in water use has not been done, but will be undertaken by the MWRA in 1994 as part of the Waterworks Division's report to the Board of Directors on MWRA's Long Range Water Supply Program.

Table 4 presents MWRA's preliminary estimates of the factors responsible for the decline of some 77 mgd of system water use from 1987 to 1992. The most significant demand management measures undertaken by the MWRA during this period have been leak detection and repair, more accurate metering, domestic device retrofitting, in addition to effecting changes in the plumbing code from 3.5 to 1.5 gallon toilets. The previous plumbing code change to 3.5 gallons is not attributable to MWRA efforts. The factor responsible for the largest decline of water has been leak detection and repair. All of this decline is due to the MWRA program. Subsequent surveys and repairs are to be conducted bi-annually by the communities.

MWRA is obliged to provide water and sewer services to 30 communities, water only to 16 communities and sewer only to 14 communities. About 80 percent of MWRA water deliveries in 1992 went to 30 communities with water and sewer services. Billing for water and sewer services is generally done on the basis of water use. Because of the recent large capital investments in the water system due to deferred maintenance and in the sewer system because of the court-ordered cleanup of Boston Harbor, water and sewer costs to consumers have risen four-fold between 1985, when the MWRA assumed responsibility for the water and sewer services, and 1992.

Recent changes in the nature and vitality of the Massachusetts economy have caused reduced water use in the MWRA service area. The Massachusetts economy has witnessed a decline in proportion of total employment in the high water use manufacturing sector and increases in the low water use service sector. Total Massachusetts non-agricultural employment

declined from about 3.1 million employees in the 1987-88 period to 2.8 million in 1991. Employment in manufacturing in Massachusetts declined from about 670,000 employees in the 1979-81 period to 599,000 in 1988 to 484,000 in 1991.

THE MWRA

Figures 4 and 5 present the organizational structure and principal functions and features of MWRA/MDC water resources planning and management for the metropolitan Boston water supply. Prior to July 1, 1985, the MDC had responsibility for all current MDC and MWRA functions. The MWRA and MDC now operate the water supply system as a partnership. The MDC manages the system's watersheds and reservoirs and the MWRA the transmission and delivery of water to the 46 communities comprising approximately 2.5 million persons. In addition, MWRA is responsible for the management of the sewerage services for the greater Boston area.

Table 4
ESTIMATES OF PORTIONS OF DECLINE (1987: 334 MGD TO 1992: 257 MGD) OF WATER USE IN THE MWRA/MDC WATER SYSTEM IMPUTED TO DIFFERENT FACTORS
(mgd)

Factors	Attributable To MWRA	Other	Totals
Demand Management			
Leak Detection and Repair			
Community Systems	30		
MWRA System	5		
Domestic Retrofit Program	8		
Plumbing Code			
3.5 Gallon Toilets		6	
1.5 Gallon Toilets	2	—	—
Sub-totals	45	6	51
Price of Water			
Indust/Commer/Instit Conservation	5	5	
Domestic Conservation (not known)	4 *	4 *	—
Sub-totals	9	9	18
Changes/Depression Regional Economy		8	8
Sub-totals		8	8
TOTALS	54	23	77
PERCENT	70	30	100

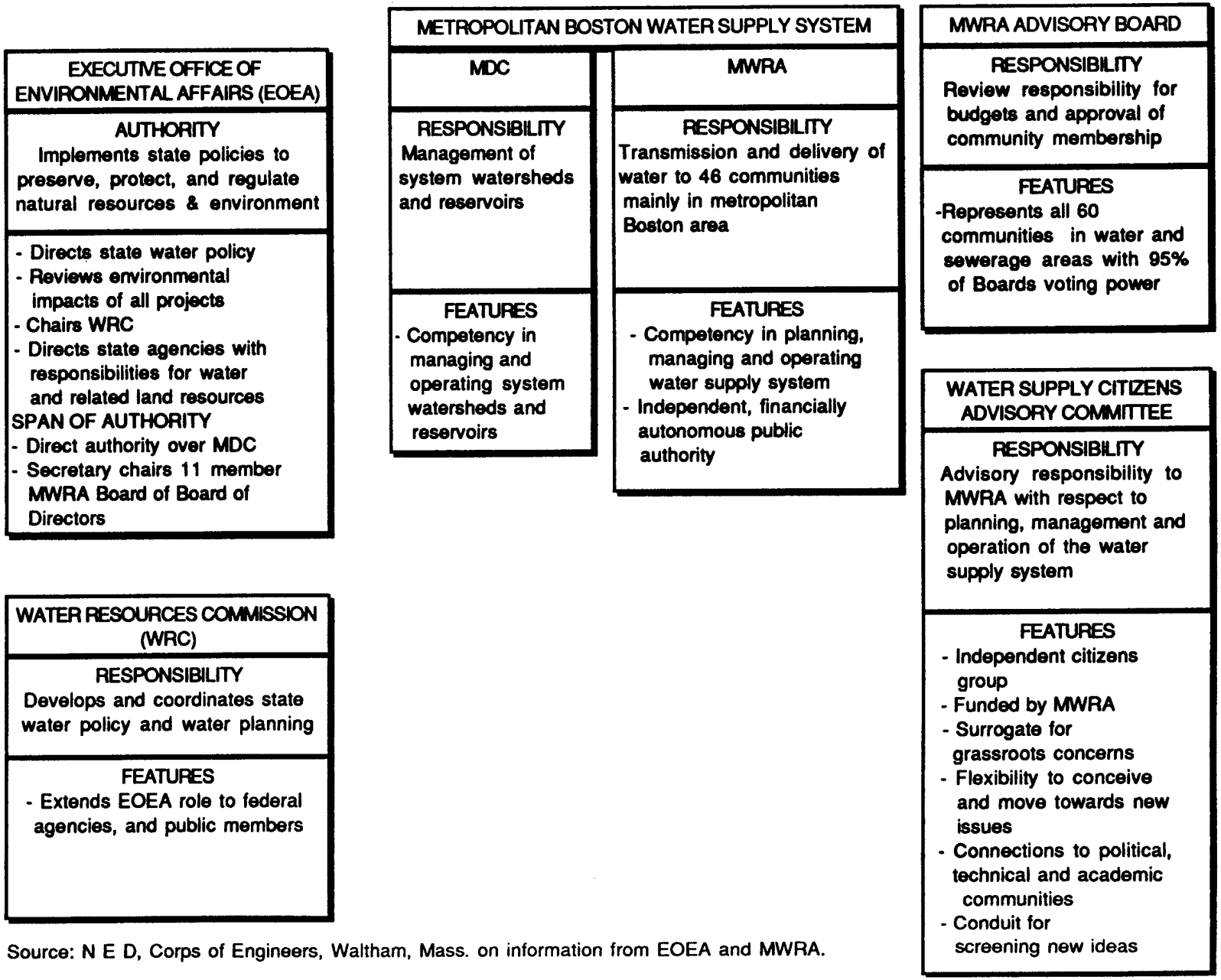
* Residual of 8 mgd (77-69 mgd) distributed between MWRA and Other.

SOURCE: Estes-Smargiassi, Stephen, (MWRA, Waterworks Division, Boston, MA.), Personal communication with Charles L. Joyce, 8 October 1993.

Figure 4

Massachusetts Water Resources Authority/Metropolitan District Commission (MWRA/MDC)

PRINCIPAL FUNCTIONS AND RESPONSIBILITIES FOR METROPOLITAN BOSTON WATER RESOURCES PLANNING PROCESS - 1993

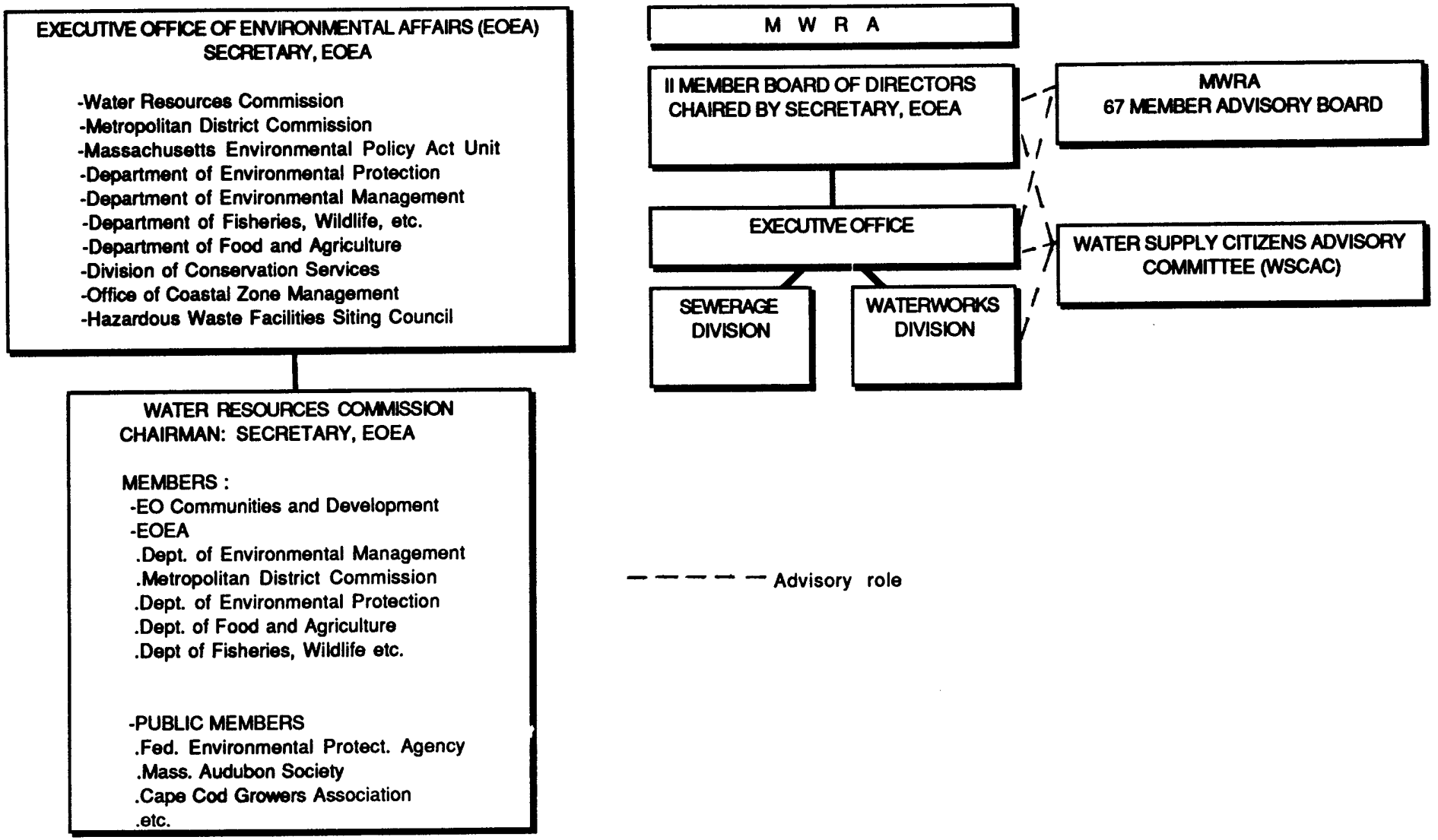


Source: N E D, Corps of Engineers, Waltham, Mass. on information from EOEA and MWRA.

Figure 5

Massachusetts Water Resources Authority/Metropolitan District Commission (MWRA/MDC)

ORGANIZATIONAL STRUCTURE FOR METROPOLITAN BOSTON WATER RESOURCES PLANNING PROCESS - 1993



Source: Massachusetts Water Resources Authority, Boston, Massachusetts

The MWRA finances its operations through the sale of water and sewer services. It is governed by an eleven member Board of Directors chaired ex officio by the Secretary of the Executive Office of Environmental Affairs (EOEA). The EOEA reviews the environmental impact of all projects through the MEPA process. This direct link to the MWRA permits the EOEA's early input into the MWRA planning process. In addition, the EOEA's authority over the Water Resources Commission (WRC) extends its span of coordination to other state and federal agencies. The WRC, using technical staff from the Department of Environmental Management, oversees the implementation of the Interbasin Transfer Act (1983) which regulates the increase or new diversion of water from one basin to another. Also the EOEA has direct authority over the DEP which is responsible for the Water Management Act (1985). Under the Water Management Act, the DEP reviews applications and issues state permits, as appropriate, for surface and ground water withdrawals over 100,000 gallons per day.

Traditionally water supply utilities have been staffed by personnel reflecting the values of the society and in turn the values of the engineering and scientific community. As such, water supply managers have been trained to build water systems in response to society's needs rather than by adjusting society's demand for water. As agencies, such as the MDC and the MWRA, broaden their perspectives beyond the supply of water to primarily urbanized communities, other factors are taken into consideration in water resources planning. This broadened perspective reflects the changing values of the society. Different water supply systems are more successful than others in reflecting the values of the society in general.

The EOEA currently requires that municipal water supply systems in Massachusetts integrate certain standards and procedures contained in the MEPA process, the Safe Drinking Water Act, the Water Management Act and the Interbasin Transfer Act into their planning and implementation processes. The interdisciplinary nature of current MWRA staff reflects the need to address these new issues.

Encouraging the Commonwealth and the MWRA and MDC into the multi-objective approach to water resources planning has been grassroots opposition to metropolitan Boston's plans in the 1960's and 1970's to meet projected imbalances in supply and demand by extending the system farther into western Massachusetts to the Connecticut River. The implementation of demand management measures, the decline of high water using industries, and depressed economic conditions, and higher costs of water to consumers have driven demand down to well below the safe yield of 300 mgd of the system. Some of the demand management measures include leak detection and repair, metering, and domestic device retrofit programs.

Today this opposition is represented by the Water Supply Citizens Advisory Committee (WSCAC). It is an independent citizens group, funded by the MWRA, to advise the MWRA with respect to the planning, management and operation of the water supply system. It has attracted a membership of scientists, attorneys, public policy advocates, and elected officials, which has made use of the political process in furthering the goals of the group. The initial citizens' concern in the 1960's and 1970's was to prevent the expansion of the metropolitan Boston water system to the Connecticut River. These concerns were defended by the group using arguments of equity and ecology: western Massachusetts residents were expected to sacrifice their resources while Easterners enjoyed abundant water. Skimming of the flood waters would invite damage to the water and related land resources. Today, the group has combined its own skills with the opportunities made possible from the information and communication revolutions to promote a managerial approach to water and related land resources planning. Formerly water supplies were designed to operate with minimum human intervention. Today's managerial approach involves continuous monitoring of system capacity and water demand relationships so that appropriate action can be taken.

WSCAC member connections with the academic, technical and political communities also allow WSCAC the opportunity to serve as a screening mechanism for new ideas and a conduit for those that are worthwhile into the water management community.

Today there is consensus between MWRA and WSCAC on the managerial approach to water resources planning for the system. According to the MWRA (See Table 4), nearly 60 percent of the decline in water use between 1987 and 1992 is attributable to changes in the management of the water system. The convergence of interests has put WSCAC and the MWRA in a win-win situation. The emphasis on water resources management works to the convenience of both entities: more efficient water use has obviated the need to seek new sources of water supply. The real test of MWRA and WSCAC's ability to develop consensus will be when their interests do not converge.

A logical extension of the MWRA/MDC water resources planning experience is a managerial approach, which was introduced by WSCAC in 1983. It is "a comprehensive, monitoring, management and planning program" called "trigger planning". This is a decision-making process which incorporates historic and operating data, physical characteristics of the system, results of demand management programs and demographic information. It provides compiled information which guides present management strategies, and facilitates the development of projections for timely decision making. (20) The objective of Trigger Planning is to "provide MWRA with the analytical tools to evaluate what projects should be built and when they are needed." (21)

An application of the Trigger Planning concept is documented in a separate report. Trigger planning integrates strategic, tactical and emergency planning into a single planning concept. It is facilitated by the use of the STELLA II interactive software model which models the MWRA/MDC water supply system physically and operationally and permits the simulation of different future strategies and their impacts on the system. The STELLA II application of Trigger Planning thus permits planners to compress space by portraying the configuration and operational features of the water system on the computer screen and to compress time by simulating different futures and instantaneously evaluating their outcomes. The interactive nature of the model facilitates the building of consensus among interested parties such as the managers of the MWRA system and the citizens group, WSCAC.

Within the context of addressing possible imbalances in the supply and demand for water in the MWRA/MDC system, trigger planning provides a framework for monitoring leading indicators of changes in supply and demand. These leading indicators are linked with strategies and appropriate actions whose implementation would ensure future system supply and demand balance. Figure 6 presents a scheme for the trigger planning concept.

PARTICIPANTS IN THE PLANNING PROCESS

The current MWRA/MDC Water System has largely been determined by the active participants in water resources planning for the metropolitan Boston area and the values that they brought to the process. Since 1985, when the MWRA succeeded the MDC in assuming all functions for the MWRA/MDC Water System for all but the system's watersheds and reservoirs, the following are the major responsible parties in the planning, management and operation of the system.

MWRA
- Board of Directors (BOD)
- Advisory Board (AB)
- Waterworks Division

MDC
- Division of Watershed Management

Forty-six communities entitled to MWRA water

Water Supply Citizens Advisory Committee (WSCAC)

Residual Massachusetts communities not in MWRA service area

See Table 5 for details of membership in the MWRA organizational entities. "The MWRA's primary mission is to modernize the metropolitan Boston area water and sewer systems, to conserve water resources and to improve the quality of water in Boston Harbor." (22) More specifically the MWRA/MDC Water System has been entrusted to ensure the legitimate water supply needs, in terms of quantity, quality and reliability for the service area communities in conformance with current laws and regulations.

Waterworks Division

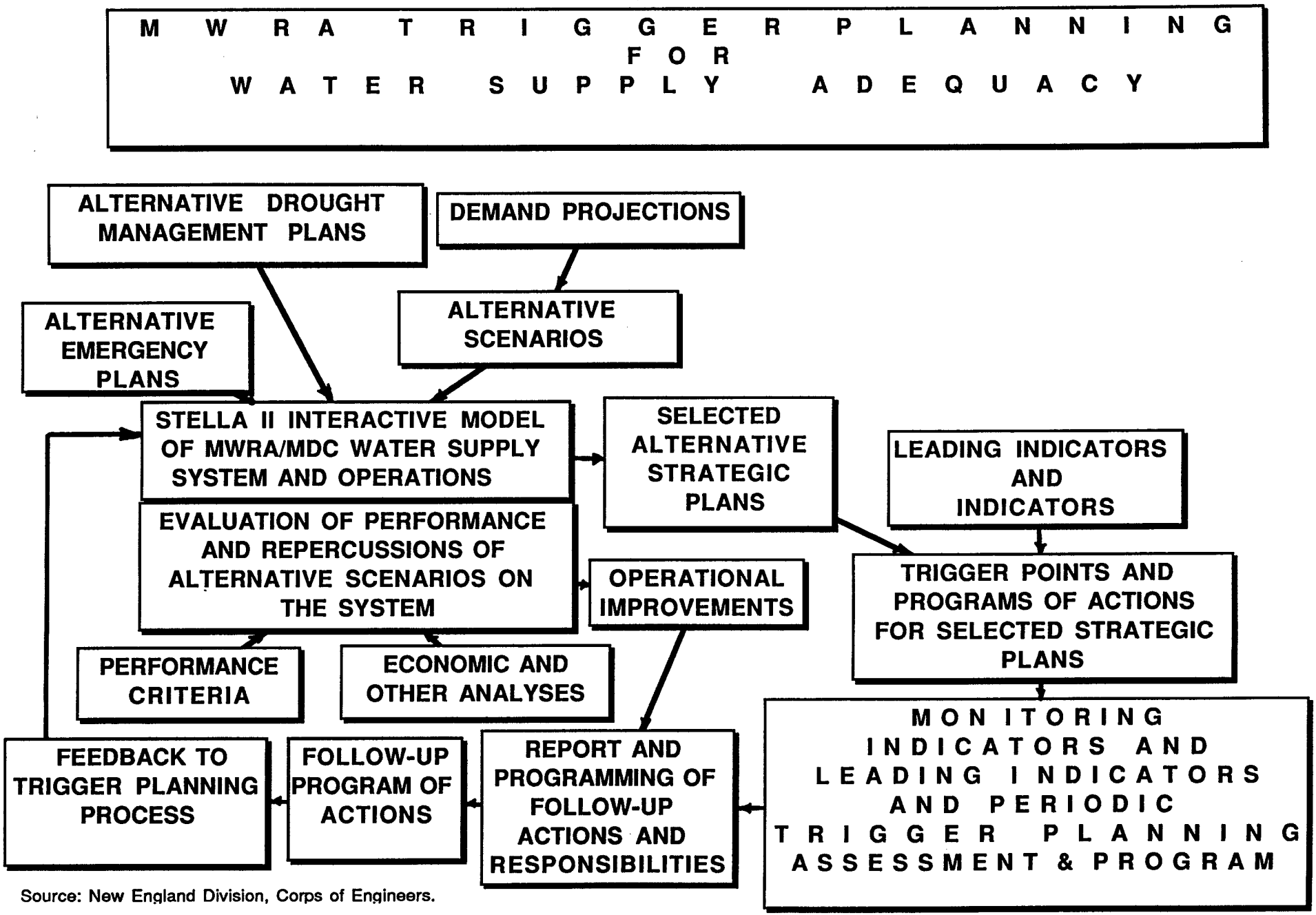
The Waterworks Division has the principal responsibility for planning for the MWRA/MDC Water System. The Division reports regularly to the Board of Directors. This report concerns the evolution of the planning and management of the metropolitan Boston water system in order to ensure the adequacy of future supply to satisfy demand. With respect to this issue, the Division recommended to the Board in 1990 that..."No decision to proceed with the development of a major new source should be taken in the next five year period." (23) The recommendation, as well as a five year program of demand management, improved use of existing and local sources, source protection, and management and planning for supply adequacy, was adopted by the Board in order to delay the implementation of supply augmentation proposals. The Waterworks Division will continue to report annually on the progress of its five year plan until 1995. The 21 October 1992 update concluded that no immediate action on supply augmentation is required by the MWRA.

Board of Directors

The MWRA is governed by an eleven member Board of Directors (BOD) chaired by the Secretary of Environmental Affairs and with three members each from the Advisory Board and the City of Boston and one member each from Quincy and Winthrop and the Connecticut and Merrimack River Basins. The Board of Directors has a representation of 45 percent from communities that are served by both the Water and Sewerage Systems, 27 percent from the Advisory Board and 18 percent from the river basins where source augmentation has been considered in the past. The BOD is weighed in favor of representation from Boston and other nearby communities using both the MWRA's Water and Sewerage Systems. Meetings of the Board of Directors require a quorum of a majority of members present and six votes for any decision.

Figure 6

The New England Drought Study



Source: New England Division, Corps of Engineers.

Advisory Board

The Advisory Board considers and makes recommendations on matters relating to the MWRA Water and Sewerage Systems including budgets and community membership in the MWRA. It holds hearings, reviews the annual report of the MWRA, prepares comments to the MWRA, and the Governor, and makes recommendations to the Governor and the general court with respect to the MWRA and its programs. The Board consists of 67 members, 60 of which represent the 60 communities in the MWRA water and/or sewer service areas with one member each. The sixty members have a combined voting strength of 95 out of 100 votes. The remaining seven members, who share 5 percent of the voting strength, consist of one each for the Connecticut River Basin, the Quabbin/Ware Watersheds, the Wachusett Watershed, the Metropolitan Area Planning Council, and one environmental expert and two qualified in water recreational or commercial Boston Harbor users. The Advisory Board is weighted favorably towards representation from the 60 member communities.

WSCAC

WSCAC, a citizens group, was established in 1977 to advise the MWRA's predecessor, the MDC, on the Long Range Water Supply Study and EIR-2020 for a large river diversion project. Today it is a MWRA funded advisory group that has been mandated to gather, formulate, and represent the public position on public policy concerning the conservation, use and development of the land and related resources affected by the MWRA mission. (24) WSCAC is particularly sensitive to the impact of MWRA policy on river basins, the equitable use of water, and on the environment. Its active membership has a particular interest in safeguarding the resources of the Connecticut River Basin.

The WSCAC office and library is located in the Connecticut River Valley in Hadley, Massachusetts. Its 1992 roster consisted of forty-one members (scientists, attorneys, public policy advocates, elected officials, etc.) representing community, regional, state, river basin, academic, environmental, health and private sector interests. Theoretically, WSCAC is the broadest based interest group of the three groups (BOD, AB and WSCAC) providing input to policy or making policy for the MWRA/MDC. WSCAC members participate early and actively in the planning process. Because of its early intervention in the planning process, the competence and commitment of its membership and the skill of individual members in interacting with the political process, WSCAC has played a significant role in water resources policy and decision-making in Massachusetts and in the MWRA/MDC Water System.

Water Supply Service Area Communities

The MWRA Water System comprises of 46 members, 32 of which are fully supplied with water, 13 partially supplied and one community (Dedham) which is entitled to be served by the MWRA but which is not. Twenty-nine of these communities are also provided with sewer services by the MWRA's Sewerage System. Fourteen other communities are also provided sewer services. A total of 60 communities are provided with water and/or sewer services by the MWRA. Member communities are primarily interested in a reliable water supply at prices that the communities consider appropriate. Communities are billed for water and sewer charges on the basis of a complex formula of water use and population. Because of the costs of the cleanup of Boston Harbor and of the investment requirements for the water system due to years of deferred maintenance, MWRA rates have escalated in the past several years. Service communities are particularly concerned with the predictions of even higher rates.

As mentioned above, member communities are favorably represented on both the BOD (72 %) and the AB (95 %). Potentially, they have considerable influence on decisions affecting the policy, development and operation of the MWRA/MDC Water System. In reality, this influence is most noticeably exerted toward the end of the planning process and prior to implementation.

Metropolitan District Commission

The MDC's Division of Watershed Management performs all planning and operational work associated with MWRA/MDC Water System reservoirs and watersheds. Division staff meet regularly with MWRA Waterworks personnel to explore issues of mutual interest.

Residual Communities in Massachusetts

Another interest group is the remaining communities in the Commonwealth of Massachusetts which may be impacted positively or negatively by the planning and development of the MWRA/MDC Water System. However, this group is not organized.

Table 5
MEMBERSHIP IN MASSACHUSETTS WATER RESOURCES AUTHORITY ENTITIES

	Water System	Water & Sewerage Systems	Sewerage System Only	Board of Directors	Advisory Board
Secretary of Environmental Affairs				1	
Connecticut River Basin				1	1
Merrimack River Basin				1	
Quabbin & Ware Watersheds					1
Wachusett Watershed					1
Metropolitan Area Planning Council					1
Advisory Board				3	
Person with expertise in Environmental Protection					1
Persons qualified with recreational or commercial uses of Boston Harbor					2
Subtotal				6	7 with 5/100 votes
WATER SYSTEM FULLY SERVED					
Arlington	1	1			1
Belmont	1	1			1
Boston	1	1		3	1
Brookline	1	1			1
Chelsea	1	1			1
Chicopee	1				1
Clinton	1				1
Everett	1	1			1
Framingham	1	1			1
Lexington	1	1			1
Lynnfield W.D.	1				1
Malden	1	1			1
Marblehead	1				1

Table 5 (continued)

	Water System	Water & Sewerage Systems	Sewerage System Only	Board of Directors	Advisory Board
WATER SYSTEM FULLY SERVED (continued)					
Medford	1	1			1
Melrose	1	1			1
Milton	1	1			1
Nahant	1				1
Newton	1	1			1
Norwood	1	1			1
Quincy	1	1		1	1
Revere	1	1			1
Saugus	1				1
Somerville	1	1			1
Southborough	1				1
South Hadley	1				1
Stoneham	1	1			1
Swampscott	1				1
Waltham	1	1			1
Watertown	1	1			1
Weston	1				1
Willbraham	1				1
Winthrop	1	1		1	1
PARTIALLY SERVED					
Cambridge	1	1			1
Canton	1	1			1
Leominster	1	1			1
Lynn	1				1
Marlborough	1				1
Needham	1	1			1
Northborough	1				1
Peabody	1				1
Wakefield	1	1			1
Wellesley	1	1			1
Winchester	1	1			1
Woburn	1	1			1
Worcester	1				1
NOT CURRENTLY SERVED					
Dedham	1	1			1

Table 5 (continued)

	Water System	Water & Sewerage Systems	Sewerage System Only	Board of Directors	Advisory Board
SEWERAGE SYSTEM SEWER ONLY					
Ashland			1		1
Bedford			1		1
Burlington			1		1
Braintree			1		1
Hingham			1		1
Holbrook			1		1
Natick			1		1
Randolph			1		1
Reading			1		1
Stoughton			1		1
Walpole			1		1
Westwood			1		1
Weymouth			1		1
Wilmington			1		1
Subtotal	46	29	14	5	60 with 95/100 votes
Totals	46	29	14	11	67
- Community Representation	46	43	14	5	60
- Percent of Community Representation	100	100	100	45	90
- Regional Representation	0	0	0	2	5
- Percent Regional Representation	0	0	0	18	7

Source: MWRA, Waterworks Division, Boston Massachusetts.

Chapter 6
LESSONS LEARNED FROM THE MWRA/MDC EXPERIENCE

The following lessons learned have been distilled from the MWRA/MDC water resources planning experience for possible application nationally for water resources and drought management planning.

EXPERIENCE/LESSON NO. 1

Experience:

The changes in water resources planning for the metropolitan Boston water supply system can be attributed to the values that participants brought to the planning process. Beginning in the 1850's the Boston Water Board established Boston as the nation's first publicly owned water supply system. The water supply system was henceforth managed by responsible government agencies staffed by municipal engineers. Engineers were trained to design and construct civil works in response to perceived future shortfalls in supply. What was best for the metropolitan Boston water system would generally be decided by the experts until the 1960's and 1970's when citizens and citizen groups from western Massachusetts objected to the augmentation of supply from the Connecticut River as a means of solving projected supply and demand imbalances.

Up to this time the needs of the manufacturing industry were implicitly and explicitly addressed in water supply planning because of the importance of manufacturing to the New England economy during these times. The needs of individual citizen opponents to water supply projects were conveyed individually, through groups and by elected officials. However, they had limited influence on the water resources planning process.

By the mid-twentieth century, manufacturing in New England had been in decline along with its interest in water resources. At the same time, some people were subscribing to new ways of using the State's water and related land resources. The spokespeople for these new interests, argued in terms of geographical equity and ecology. They were youthful, more environmentally conscious and more knowledgeable of the issue than the average citizen. In the case of Massachusetts, these interests were situated in the Connecticut River Valley in western Massachusetts where planners proposed to tap new supplies. They also had links to the academic communities centered around the University of Massachusetts in Amherst.

Lessons Learned:

Entities responsible for municipal and industrial water supplies should take into account the views of those who could potentially be affected by the decisions made in managing the system. The MWRA/MDC experience demonstrates that these views

emanate from geographical areas from which new sources of water could be drawn and from current and future water users.

The openness of the entity to new ideas can be fostered by links to universities and citizens groups which can distill the more lasting movements from the fads and by the recruitment of staff trained to go beyond the limits of their own educational boundaries in seeking solutions to water resource problems.

Entities responsible for M&I water supplies should provide feedback to the colleges, universities and other training facilities for water supply planners, engineers and technicians in terms of the problems and issues confronting practitioners of M&I water supply planning and operations with the view to curriculum betterment.

EXPERIENCE/LESSON NO. 2

Experience:

Planning for the metropolitan Boston water supply had been dominated by the values of the engineering community from about 1850 to the 1960's. The efforts of citizens and citizen groups to participate in the planning process was polarized in 1960's, and 1970's by plans to balance projected supply shortfalls, precipitated by the 1960's drought, by the augmentation of supply from the Connecticut River. The result today is that the MWRA/MDC, which operates the water supply system as a partnership is assisted by the Water Supply Citizens Advisory Committee (WSCAC). WSCAC is an independent citizens group and funded by the MWRA to advise the MWRA in the planning, management and operations of the water supply system. WSCAC membership covers a wide spectrum of geographical and other interests and as such serves as a surrogate for many of the issues that confront water supply planners. The organization's efforts have been devoted to issues directly related to the resources of river basins and particularly the Connecticut River Basin. WSCAC's participation, as an early critic, influences the planning process and reduces the risk that recommendations would encounter opposition further on in the planning process.

The MWRA/MDC experience suggests that the creation of a group of informed citizens, whose membership reflects the interests and issues that the entity is encountering and likely to encounter, is a good investment. The integration of relevant issues early in the planning process permits planners and citizens to stand together to encounter and resolve issues thereby moving the dialogue from confrontation to consensus and finally to commitment. Citizen participation by WSCAC in the MWRA/MDC water resources planning process has been characterized by:

- an independent, full-time staff that is financed by the M&I utility, but answerable only to the citizens' group,

- credible citizen participation to bring public opinion into the water resources planning process and to ensure that the public is generally satisfied with the outcome, (24) or aware that their views have been heard,

- public participation of competent, committed and connected citizens with the interdisciplinary and political skills, and devotion to effectively represent public issues,

- a screening mechanism to separate fads from long-term public concerns and the flexibility to move toward and represent these concerns.

Lesson Learned:

M&I water system management should encourage an openness to the values of all citizens and citizens' groups with respect to the planned use of water and related land resources. Citizen participation, as an early critic, enriches the planning process and reduces the risk of unanticipated opposition further on in the planning process.

EXPERIENCE/LESSON NO. 3

Experience:

Although the managers of the metropolitan Boston water system demonstrated an initial reluctance to public demands for greater participation in the planning process, after some time they were persuaded of its merits. As a result the Northfield Citizens Advisory Committee, later named WSCAC, became an official partner in planning for what was to become the MWRA/MDC Water System. As a result the MWRA was established and consensus generated programs (demand management, Long Range Water Supply Program, etc.) responding to both managerial directives and public concerns were adopted, funded and committed and competent interdisciplinary staff engaged.

Lesson Learned:

Not only is it desirable to encourage public participation in the water systems planning process for the reasons stated in Experience/Lesson No. 3 above, but also system managers should be motivated to be receptive to public input that responds to effective management, as well as, public concerns. Consensus generated programs should be adopted and funded and committed and competent staff engaged to undertake them.

EXPERIENCE/LESSON NO.4

Experience:

MWRA, which became operational in 1985, is an independent and financially autonomous public authority responsible for the delivery and distribution of potable water to 46 communities mainly in the metropolitan Boston area. Its financial autonomy permits the MWRA to operate as a business in which revenues from the sale of water and financial instruments such as bonds are used to finance capital and recurrent costs. The MWRA succeeded the MDC in these functions. MDC's dependence on the Massachusetts legislature for capital and operating funds resulted in years of deferred maintenance.

Lesson Learned:

Entities responsible for the delivery and distribution of M&I water should be independent and financially autonomous in order to permit them to plan and execute the most cost effective ways of carrying out their missions and to raise the required funds to support their programs.

EXPERIENCE/LESSON NO. 5

Experience:

The experience of WSCAC and its predecessor citizens groups has been one of changing tactics to impede the use of the Connecticut River as a means of balancing projected shortfalls in the supply and demand for water for the metropolitan Boston area. Initial opposition was based on equity: metropolitan Boston should curb its appetite for new sources of water by generally managing its system more efficiently to reduce waste. Added to these arguments were those which opposed the use of the Connecticut River for ecological reasons. After the issuance of the 1975 Curran Study (25), which identified a large amount of unaccounted water in the system, the citizens realized that their cause could be furthered by more efficient management of the system and more specifically by considering water demand as a variable in order to balance future supply and demand. Largely through their efforts, demand projections were reevaluated and adjusted downwards, and leak detection and repair became part of managements' tools to reduce water use by millions of gallons per day. Concurrently with the implementation of demand management measures, water use declined due to changes and the downturn in economic conditions and increases in the cost of water.

Lesson Learned:

The nation's entry into the information and communications age has put tools at the disposal of water systems that permit more efficient system management. The adoption of improved water supply management practices, including demand management, conjunctive use of surface and
ground water resources, water exchange agreements, etc. to fine tune M&I water systems can permit managers to wring additional usage out of their systems without incurring the additional capital costs associated with large projects. In addition, the adoption of these practices improves the credibility of M&I system managers and reduces
discord between managers of the system and those citizens and citizens' groups primarily interested in protecting other basin water resources for current and future uses.

However, the implementation of demand management practices for more efficient water use, may diminish the ability of system managers to respond to drought. Certain actions, such as reductions in water use by large users, are common to both demand and drought management. As demand management becomes part of normal operations of the MWRA/MDC Water System, the amount of water use reduction that could be anticipated from drought actions (see Table 3) may effectively be decreased, thereby trimming the potential reductions that could be expected from the implementation of the Drought

Management Plan. In addition, the trimming of this margin increases the risk of water shortage due to the unwillingness or inability of system managers to call for more frequent and/or more stringent drought actions from consumers than are included in the current Drought Management Plan. Also, in the event that more stringent drought actions are effectively imposed, consumers may react strongly to the consequent need for changes in their life-styles.

The implementation of demand management practices along with other factors, such as the changing and depressed economy experienced by the metropolitan Boston area and increases in the price of water, have caused a dramatic fall in water use in the MWRA/MDC Water System service area in recent years. However, reduced demand may require increases in water rates in order to permit utilities to recover the costs of system operation. Utility managers and consumers alike are frustrated by the necessity to increase water rates and the costs of water to consumers at times when consumers are cooperating with demand management efforts to reduce water use. In addition, pressure on water rates is exacerbated by the need to fund deferred improvements to the water system.

EXPERIENCE/LESSON NO. 6

Experience:

Historically long range or strategic planning of water resources undertaken by MWRA and its antecedent agencies has been episodic. It has taken the form of periodic assessments of future demands on the system and of the system's capacity to satisfy these demands. These assessments were followed by system improvements or decisions to postpone improvements and then succeeded by periods in which the system would generally be expected to run on its own. More recent MWRA/MDC planning experience can be characterized as interventionist. Rather than permit a water system to move towards the inevitability of a future situation, system managers take action to direct the system to a preferred future.

MWRA system managers and WSCAC staff alike are concerned that episodic water resources planning practices could lead to a failure of managers to anticipate a shortfall in supply leading to crises management of the water supply system and premature investment in structural solutions. These situations can result, for example, from a failure to monitor the degradation of local sources of water for the communities that are currently partially supplied by the MWRA thereby adding to the demand on the system.

Lesson learned:

The present application of Trigger Planning for supply adequacy is a comprehensive decision-making process that integrates strategic, tactical or drought contingency, and emergency water resources planning into a single management approach. This approach avoids the drawbacks of episodic planning, such as permitting the water system to move towards the inevitability of an undesirable future situation and

premature investment, and translates into the postponement of thresholds at which drought emergency measures and long term supply augmentation would have to be considered and/or implemented. This application of Trigger Planning is of particular significance for systems with large over year storage where reductions in demand during droughts can be carried over into successive years thereby enhancing the system's long term adequacy.

Chapter 7
THE BOSTON PROTOTYPE: WATER RESOURCES PLANNING FOR MUNICIPAL AND INDUSTRIAL WATER SUPPLY SYSTEMS

Figure 7 presents a schematic of the planning experience for the water supply system for the metropolitan Boston area. As described earlier, the response of planners for the metropolitan Boston water supply system to the 1960's drought precipitated a debate between the operators of the system and interested citizens and citizens' groups who were opposed to a proposed supply augmentation from the Connecticut River. Since that time planning has evolved from a classical or episodic approach to a managerial approach.

The episodic approach was characterized by periodic assessments of future demands on the water system and of the system's capacity to satisfy these demands followed by system improvements and then succeeded by periods in which the system would be expected to run on its own. Supply was considered to be variable, that is, new sources could be found. Future demand was based on projections of population and water use and these were considered to increase in the future. The classical approach favored structural solutions to potential shortfalls in water supply.

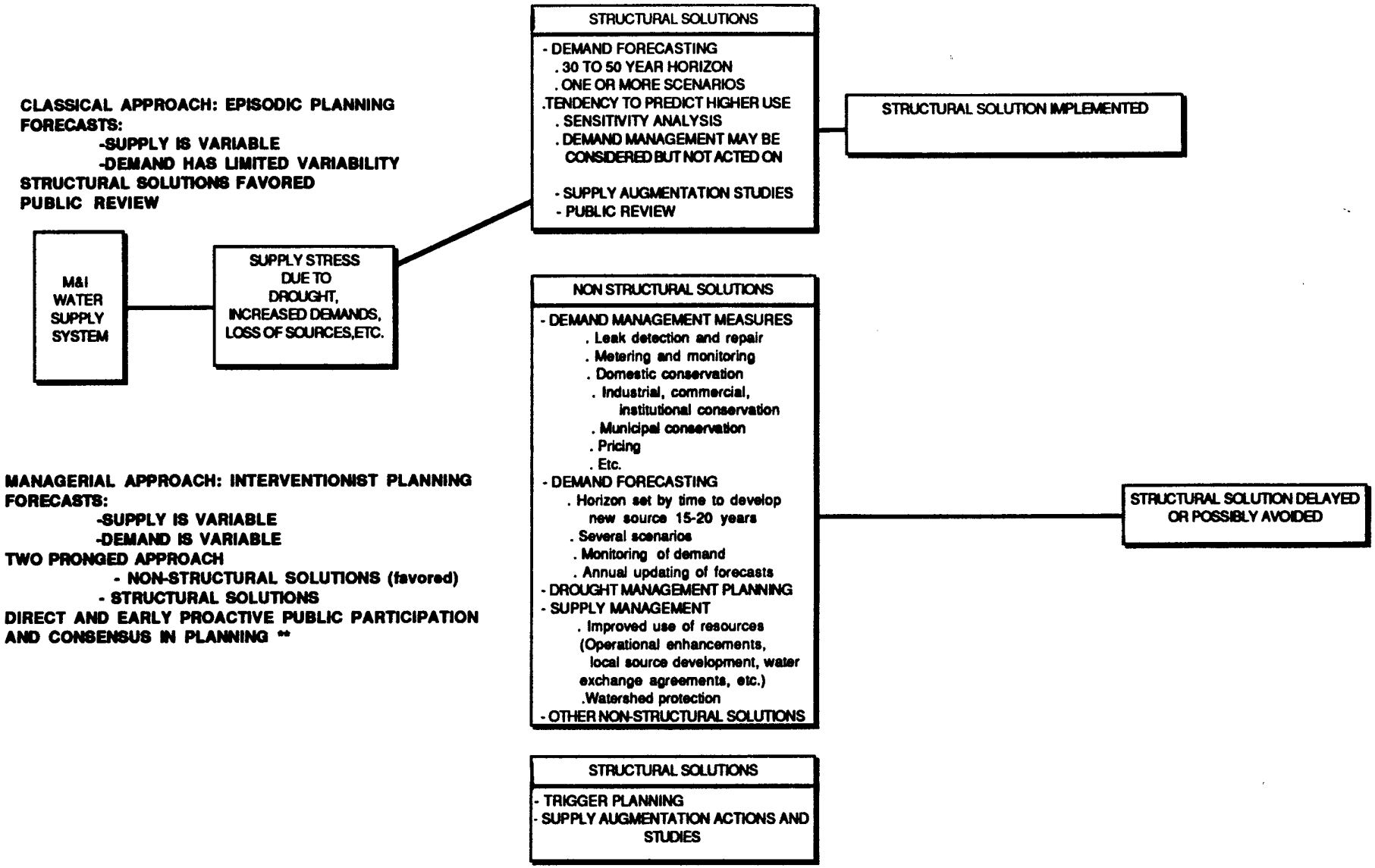
Today, the managers for MWRA/MDC Water System employ a managerial or interventionist approach to planning. Rather than permit a system to move toward the inevitability of a future situation, whether desirable or undesirable, system managers take action to direct the system to preferred future. A two pronged approach to potential shortfalls in supply is employed: non-structural and structural solutions. The approach involves systematically monitoring supply and demand while both undertaking the necessary actions to avoid a supply shortfall and preparing to undertake structural solutions if they become necessary.

Non-structural solutions involving demand and supply management, drought management planning, shorter horizon demand forecasting, etc. are designed to wring more use from the current water supply infrastructure through more efficient water use while reducing potential system use through conservation. A separate report entitled, Trigger Planning: Integrating Strategic, Tactical and Emergency Planning into a Single Water Resources Management Process, documents MWRA's efforts to apply a Trigger Planning process to planning for future water supply adequacy. The study enables the MWRA to determine which of a number of water supply actions, whether structural or non-structural, to implement and when to implement them.

The Trigger Planning process identifies and monitors leading indicators of changes in supply and demand and links them with actions designed to ensure the sufficiency of supply. Large projects are implemented only if it becomes clear that an unacceptable level of risk to supply adequacy will occur if action is not taken.

Figure 7
The New England Drought Study

THE BOSTON PROTOTYPE: DEMAND AND SUPPLY MANAGEMENT FOR MUNICIPAL AND INDUSTRIAL(M&I) WATER SUPPLY SYSTEMS*



* Based on the water resources planning experience of the MWRA/MDC Water System for the metropolitan Boston area

** In the Boston experience, local citizens were organized behind a compelling issue: opposition to a plan to augment the water supply to metropolitan Boston from the Connecticut River.

SOURCE: The New England Drought Study

Chapter 8
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- 10 March 1992: Julia O'Brien, Director of Planning, MDC, Boston, MA.
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- 8 April 1992: Elizabeth Kline, Director of the Consortium for Regional Sustainability, Center for Environmental Management, Tufts University, Medford, MA.
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ATTACHMENT A

ENGINEERS IN THE UNITED STATES - 1900-1990

Prior to 1816 fewer than thirty engineers could be found in the United States and for the most part, these were trained elsewhere. The United States Military Academy West Point was established in 1802 to become the first school for the training of engineers in the United States. It was not until 1846 that Harvard and Yale added science to their curriculums. Also schools to train civilian engineers were being created. By 1870, twenty-one engineering schools or faculties existed and by 1896, there were 110 such schools. (2) Indicative of the growth of civil engineers is 20,000 active civil engineers in the U.S. at the turn of the century to approximately 253,000 by 1990 and an increase of engineers of all persuasions for the same period from 38,000 to about 1.7 million. See Table A-1.

Table A-1
ECONOMICALLY ACTIVE UNITED STATES ENGINEERING POPULATION
(thousands)

Year	Total Engineers	Total Civil Engineers
1990	1,708	253
1980	1,382	200
1970	1,230	175
1960	872	158
1950	543	128
1940	297	97
1930	217	88
1920	134	56
1910	77	40
1900	38	20

Sources:

1900-1970: U.S. Department of Commerce, Bureau of Census, Statistical History of the U.S. from Colonial Times, 1976.

1980: U.S. Department of Commerce, Bureau of Census, 1980 Census of Population and Housing, Occupation by Industry.

1990: U.S. Department of Commerce, Bureau of Census, 1990 Census of Population and Housing, Equal Employment Opportunity File.

ATTACHMENT B

NATIONAL STUDY OF WATER MANAGEMENT DURING DROUGHT REPORTS

The National Study of Water Management During Drought: Report on the First Year of Study (IWR Report 91-NDS-1) prepared by the Institute for Water Resources, U.S. Army Corps of Engineers, Fort Belvoir, Virginia.

A Preliminary Assessment of Corps of Engineers Reservoirs, Their Purposes and Susceptibility to Drought (IWR Report 91-NDS-2) prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California.

An Assessment of What is Known About Drought (IWR Report 91-NDS-3) prepared by Planning and Management Consultants, Ltd., Carbondale, Illinois.

Lessons Learned from the California Drought (1987-1992) (IWR Report 93-NDS-5) prepared by Planning and Management Consultants, Ltd., Carbondale, Illinois.

A number of reports presenting the final results of the National Study will be published in the Summer of 1994. Among these reports:

The National Drought Atlas (IWR Report 94-NDS-4) is a compendium of statistics which allows regional water managers to determine the probability of droughts of a certain magnitude and duration.

Executive Summary: Lessons Learned from the California Drought 1987-1992 (IWR Report 94-NDS-6) is a concise summary of NDS-5 (above), with some new information that became available after NDS-5 was published.

Computer Models for Water Resources Planning and Management (IWR Report 94-NDS-7) summarizes brand name models in eight categories: general purpose software (such as spreadsheets), municipal and industrial water use forecasting, water distribution systems (pipe networks), groundwater, watershed runoff, stream hydraulics, river and reservoir water quality, and river and reservoir system operations.

Drought Impacts in a P&G Planning Context (IWR Report 94-NDS-9)

Human and Environmental Impacts: California Drought 1987-92 (IWR Report 94-NDS-10) NDS-9 is a collection of papers by California researchers who attempted to measure the impacts of the drought on the California economy and environment. NDS-10 shows how drought impacts can be measured in the accounting system of Principles and Guidelines. It uses the results of NDS-8 as an example.

Water Use Forecasts for the Boston Area Using IWR-MAIN 6.0 (IWR Report 94-NDS-11) demonstrates one of the first uses of a beta test version of the new generation of MAIN. The objective of this study was to determine the relative effectiveness of long term water conservation measures.

National Study of Water Management During Drought: Report to Congress (IWR Report 94-NDS-12) summarizes the results of the study and responds to the questions around which the study was designed.

Trigger Planning for the MWRA Service Area (IWR Report 94-NDS-13) documents the development of what might be called "just in time" water supply enhancement; a management system that can reduce economic and environmental investments in supply and demand measures while maintaining necessary water supply reliability.

Government and Water Management During Drought (IWR Report 94-NDS-14). Prepared by the Advisory Commission on Intergovernmental Relations (ACIR). NDS-14 addresses the general subject of technical water management within the American democratic process. It includes papers on law, decision making, public involvement, and two case studies that provided information on political decision criteria to water managers.

Colorado River Gaming Exercise (IWR Report 94-NDS-15) documents the use of a shared vision model on a gaming exercise to evaluate operational and institutional alternatives for the management of the Colorado River. This report was prepared as a joint project with the Study of Severe Sustained Drought in the Southwest United States.

Shared Vision Models and Collaborative Drought Planning (IWR Report 94-NDS-16) prepared by the University of Washington for the Corps of Engineers, documents the use of the shared vision model in the National Drought Study case studies.

Lessons Learned in the National Drought Study Case Studies will be published in the Fall of 1994, contingent on the completion of the Marais des Cygnes-Osage DPS, which was delayed by the flooding on the Missouri River during the Summer of 1993.

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